Popular Astronomy.

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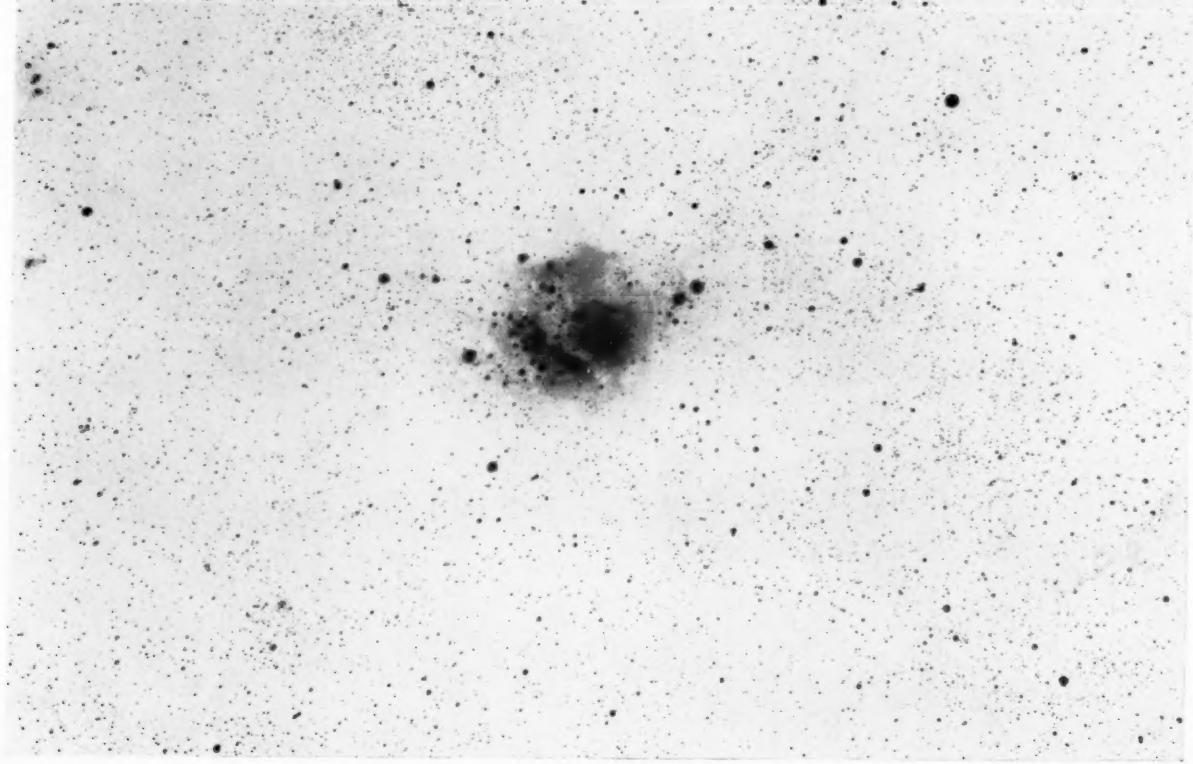
THE BRUCE PHOTOGRAPHIC TELESCOPE.

EDWARD C. PICKERING.

The advantages of a doublet for photographing the stars were advocated by the writer in 1883 (Astron. Register XXI, 151, Observatory VI, 201) and again in 1886 (Mem. Amer. Acad. XI, 179). In the latter article (p. 207) it was urged that charts should be photographed of the same size and scale as the charts of Peters and Chacornac, that is on a scale of 6cm. to 1°, and covering a region 5° square. It was there proposed that photographs taken with the 8-inch Bache telescope should be enlarged three times. A similar plan was recommended to the Congrès Astrophotographique International in a letter dated December 10, 1887 (Annexe, No. 5, p. 95). Later it was shown in a paper presented to the National Academy at a meeting held in Washington in April, 1888, that the best results might be expected from a telescope having an aperture of 60cm. and a focal length of 343.8cm. The same plan was recommended in a circular dated November 20, 1888, and entitled, A Large Photographic Telescope. The generous liberality of Miss Catherine W. Bruce (The Bruce Photographic Telescope, June 26, 1889), permitted this experiment to be tried. The instrument was constructed by Messrs. Alvan Clark & Sons, and was mounted provisionally and tested in Cambridge. It was sent to Arequipa last winter by way of the Straits of Magellan, thus avoiding the dangers of transshipment upon the Isthmus of Panama. It arrived safely in Arequipa, was mounted successfully, and is now kept in constant use by Professor Bailey. The excellent results since attained with it are largely due to his skill and perseverance. The accompanying plate serves to illustrate the work already accomplished with this instrument. The original negative was taken on June 11, 1896, with an exposure of 180 minutes upon a plate 14 x 17 inches. The region covered extends in right ascension from $17^h\ 40^m$ to $18^h\ 10^m$, and in declination from $-20°.8$ to $-26°.5$. About a quarter of this region is represented in the accompaning figure. The upper of the two nebulæ is the Trifid Nebula, N. G. C. 6514. The lower and larger nebula is N. G. C.

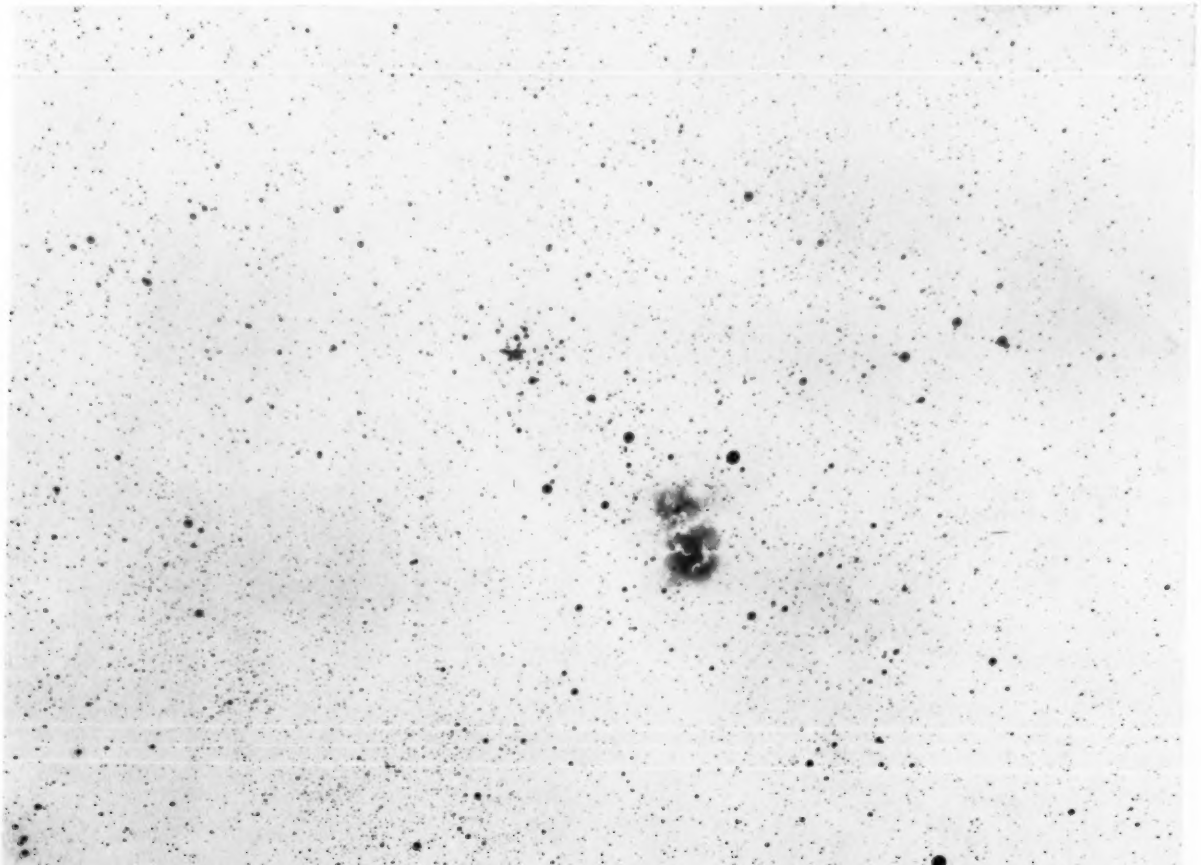
6523. While this form of photo-engraving is convenient to give a general idea of the appearance of the original negative, it is not adapted to a careful study of the plates. The images are formed of black dots upon a white background and accordingly it is impossible to derive from them the true relative positions or magnitudes of the stars represented, as is obvious if they are examined by a magnifying glass. Photogravures have accordingly been prepared of two regions, and a limited distribution, mainly to observatories, is being made of them. They are produced by contact printing from the original negatives and carry out the plan of mapping described above. That is, the photogravures are on a scale of one minute of arc to a millimetre, and cover a region five degrees square. Plate I represents the region whose centre is in R. A. $16^h\ 10^m$, Decl. $-52°$. The original negative was taken on June 6, 1896, with an exposure of 62 minutes. The cluster in the lower part of the plate is N. G. C. 6069. Plate II represents the region whose centre is in R. A. $10^h\ 40^m$, Decl. $-59°$. The original negative was taken on June 1, 1896, with an exposure of 240 minutes. The images are elongated, and this plate is issued as an example of the enormous number of stars which can be shown upon a single map, while Plate I illustrates the character of the images at the centres and corners, and the quality of maps to be expected. It is proposed to issue, from time to time, maps of other portions of the sky, such as the Magellanic Clouds. According to the original plan a map of the entire sky on the scale here represented was to be published. To avoid duplication of work this plan has been abandoned, since the Astrophotographic Congress has undertaken to supply this want. It is believed that a less expensive and more useful scheme will be to furnish contact prints on glass from the original negatives, to such astronomers as will make use of them. A double contact print so closely resembles the original negative that it can only be distinguished from it with difficulty, and for purposes of measurement or exact study is, of course, far more valuable than any paper print.

While announcing the successful completion of the Bruce Photographic Telescope, attention should be called to the courage of the donor who permitted an experiment to be tried on a scale never before attempted, and whose liberality, both in the amount of her gift and in the terms on which it was made, rendered every aid to secure success. It is a great satisfaction to be able to show by these photographs that the results obtained are exactly as expected, and that no unforeseen difficulty interfered with the



CENTRE, R. A. = $17^{h.}\ 56^{m.}$ Dec. = $-\ 23^{\circ}\ 7$ TRIFID NEBULA.
Taken June 11, 1896. Exposure $180^{m.}$ Scale $1' = 0.1$ cm.

THE BRUCE PHOTOGRAPHIC TELESCOPE.



success of the experiment. Excellent results have already been obtained in photographing the spectra of very faint stars with prisms placed over the object glass of this instrument, and they will be made the subject of a subsequent circular.

HARVARD COLLEGE OBSERVATORY,
Circular No. 15, December, 30, 1896.

THE PHYSICAL SIGNIFICANCE OF THE ROTATION PERIODS OF MERCURY AND VENUS ESTABLISHED BY MR. LOWELL'S RECENT OBSERVATIONS.

T. J. J. SEE

FOR POPULAR ASTRONOMY.

Mr. Lowell's recent observations of Mercury and Venus and the important conclusions he has been enabled to draw from them possess a very high interest for astronomers who are concerned with physical causes which have operated in past ages and thus shaped the phenomena now observed in the solar system. The definite observational proof that these two planets rotate once only in the course of their orbital motions about the Sun, and thus show one hemisphere only towards that body is an achievement of high importance in the history of astronomy, and philosophically of the greatest significance, since it furnishes additional observational proof of the operation of tidal friction as a general physical cause affecting the motions of systems in space.

The credit for the establishment of these important facts of observation may be divided between the illustrious Italian astronomer, M. Schiaparelli, and Mr. Lowell; the former being the first to re-examine the long accepted but erroneous rotation periods of these planets, and to render the present results highly probable; the latter being the first to furnish a decisive proof that no other periods than those of the sidereal revolutions could account for the observed phenomena. Schiaparelli will always have the credit for having reopened these questions to new investigation, and for making observations near the middle of the day, when the glare of the planets is removed by the light of the Sun, and the observer is able to detect delicate markings otherwise invisible, as well as for securing results for Mercury which were practically conclusive as to the rotation period. Lowell is entitled to the credit for having examined these questions anew, under conditions entirely independent of those of his predecessor, and for

extending his observations over all hours of the day, so as to finally exclude a period of about 24 hours, which had remained a possibility, especially as regards Venus. By observing the planets from the early hours of the morning till late in the afternoon it was found that no measurable change in the markings had occurred in eight hours, and hence the only possible explanation of the phenomena was to be found in the longer period of rotation suggested and rendered probable by the previous work of Schiaparelli. Lowell's work on the physical features of Venus has also thrown much new light on the general character of the planet's surface, and enabled us for the first time to construct a fairly accurate map of the hemisphere illuminated by the Sun. It will be an interesting question for the future to see if the phosphorescent phenomena observed on the dark side will enable us to depict the more conspicuous phenomena of the other hemisphere, and thus to map the surface details of the entire globe.

Now that the periods of rotation are definitely settled it is a matter of great satisfaction to know that at least three bodies in the solar system—the Moon, Mercury and Venus—show the effects of tidal friction upon their axial rotations. By the labors of the younger Darwin it has been known for about 18 years that such an outcome was the ultimate result of the tidal retardations of the axial rotations of the planets arising from the gravitational action of the Sun; and it would naturally be supposed that those bodies nearest the Sun would be the first to exhibit the effects predicted from theory. For the rate of retardation of axial rotation varies inversely as the sixth power of the distance of the tide-raising body, and it would thus rapidly exhaust the rotational moments of momentum of those planets which are nearest the Sun, while those more remote would be affected to a much less extent. Except for the large density of the Earth and the correspondingly large moment of momentum of axial rotation with which it was originally started, we should now have a day much longer than that of Mars, so that the duration of the day would decrease as the planets recede from the Sun; but the periods of given planets are modified by circumstances of their formation and secular cooling and consequently the law exemplifying the working of tidal friction is partially obscured by other causes. The results however, in the case of the Moon, which is so near the Earth, and of Mercury and Venus which are so near the Sun, show a striking accordance of observation with theory, and do not permit us to doubt that the agency of tidal friction first carefully investigated by G. H. Dar-

win is a physical cause of the utmost generality, in importance second only to gravitation itself.

The recent researches of the writer have made known the operation of this agency among double stars in the most remote regions of the heavens, and now we seem to realize for the first time the grandeur of the Newtonian Law, and of the general phenomena of tides in the actual universe, composed principally of masses of self-luminous fluid, such as the stars and nebulæ. All systems of fluid bodies like the double stars and double nebulæ are necessarily subject to the secular effects of tidal friction, and any traces it may have left upon their orbits, such as their high eccentricities, will enable us to trace their development through immeasurable ages and to throw light upon the past conditions of the systems of the universe.

It is not probable that Uranus and Neptune, the other two planets whose rotation periods are still unknown, rotate in the same time in which they revolve in their orbits, nor is this likely to be true even of the larger asteroids. But it is almost certain that some of the satellites of Jupiter and Saturn will have rotation periods identical with their sidereal revolutions, and a strong probability of the same phenomena is presented in the case of satellites of Mars and Uranus and Neptune. Whether observers will be able to determine these interesting questions of fact can be decided only by time and experience, but we may not hesitate to say that every discovery of such a phenomenon is a contribution of high importance to the data of astronomy.

If Laplace justly considered his discovery of the cause of the libration of Jupiter's satellites to be one of his greatest achievements, well may we be excused for ranking the theory of tidal friction and its verification by observation among the greatest achievements of the present century. If it can be definitely established by direct and incontrovertible evidence that a satellite of Jupiter or Saturn rotates once only in the course of a sidereal revolution, the achievement will not be one whit inferior to the discovery of Neptune, except that the method involved in the one case was that of mathematical theory, while in the other it would rest on a critical analysis of refined observations of the highest precision. The discovery of Neptune confirmed in a striking manner the accuracy of the Newtonian law; the discovery that a satellite's rotation had been exhausted by the tidal action of the planet would constitute a similar verification of the operation of tidal friction, which among the fluid masses of the actual universe is a physical cause as universal as gravitation itself.

Lowell Observatory, City of Mexico, 1897, Feb. 22.

THE STUDY OF VARIABLE STARS. III.

PAUL S. YENDELL.

For Popular Astronomy.

o Ceti (Mira).

With the beginning of the present series of observable maxima *o* Ceti, communications indicating the awakening of a considerable interest in the star have appeared in various astronomical publications.

Within the past year or two, various expressions of dissatisfaction with the state of our knowledge of the law of the star's variation, and intimations that the case must have been neglected, have come to my notice. These have all, so far as I know, been the utterances of persons of small experience in the observation and practical study of variable stars, who are unacquainted with the character of the problem, and the labor involved in an attempt at a new solution; a labor, which, as well as the difficulty of the problem itself, increases with the increase in the mass of accumulated data, and requires an experience, a fund of patience, and a ripened judgment, which are exceedingly rare.

Mira is one of several of the longest known variables, the laws of whose variations seem to defy investigation, and which continually depart from the most carefully prepared elements. In such a case the only course open is to wait patiently until still fuller data are supplied by years of observation.

In view of these facts, it seems to me that a résumé of our present knowledge of the star would be of interest, and of possible value.

The following historical account is abridged from the one in the second part of Vol. VII of the Bonn Observations written by Argelander, who presumably had access to the original documents. The original is exhaustive up to the year 1860, and my version follows the text as fully and closely as seems admissible in a paper of the scope and character of the present one.

The first notice of this remarkable star is found in Kepler's *Optik*; it is very brief, and says only that Fabricius had sent Tycho some observations of the distance of Mercury from a bright star in the Whale, which neither himself nor any one else had been able to find again.

Kepler speaks more particularly about the observations of Fabricius in his treatise on the new star in Serpentarius. But the statements there made seem to be incorrect in many essential particulars, as appears from the later letters from Fabricius to Kep-

ler, for which we are indebted to Frisch, in his new edition of Kepler's works.

The second of these letters was probably sent in duplicate, as is expressly stated of a later one. At least Frisch gives the date, "Ostelac die 14 Jan. 1605," while the letter in the Pulkowa collection bears the date "Aurici Frisiæ die 16 Jan. 1605." The contents of both are the same, except for some unimportant differences. From all these letters it appears that it was not Mercury, but Jupiter, whose distance from the new star Fabricius had measured. This is not entirely unimportant, as it certainly does incline us to assign the observation to an earlier year. Mercury was very near its greatest elongation on Aug. 3, 1596, O. S., and was 10° high when the Sun was 10° below the horizon. But its distance from Mira was more than 90°, and Fabricius would certainly not have selected the latter for a comparison-star. In the later letters, Fabricius gives the distance from the planet as 20° 35′, which for the rough observing of that time fits Jupiter very well, as computation gives it as 20° 21′.

The other two differences are more important. Kepler says that the star was of the third magnitude, while Fabricius in the different letters constantly calls it second. The statement in both letters that it was "*paullo major stellis tribus in capite Arietis*" certainly does not show great closeness in the magnitude estimates, since these three stars, α, β and γ, are respectively of the 2d, 3d and 3.6 magnitude, and we might doubt the accuracy of the 2d magnitude which was assigned to the star in the meridian observation of Aug. 11; but in any case the star must have been conspicuously bright, and cannot have been long past its maximum.

Further it appears in the earlier statement that the star disappeared in October; in the first of the letters, "*in Octobri evanuit*," in both versions of the second "*post Michaelis festum evanuit*," in the last "*quam 96 in Aug. et Sept. observavi.*" So that we must assign the disappearance to the beginning of October, O. S.

The last letter, 1609 Mar. 12, O. S., is of especial value in that it contains the mention of a second appearance of our star. Fabricius saw on 1609 Feb. 5, in the constellation of the Whale "*stellam insolitam*," which he immediately observed, and found it to be the same that he had observed in 1596; at the end of February he still saw it, but when he wrote the letter, he could no longer be sure of it on account of the moonlight, though had this been absent, he could no longer have seen it in the strong twilight.

It is inconceivable that Fabricius should not have looked again during the following winter for the star which he had observed at two different epochs, especially as he in several places expresses his opinion that the new stars are constantly present, though dark, and only become luminous from time to time, to announce unusual events.

So the matter rested for nearly thirty years, until a new chance occasioned the rediscovery of the star. The fortunate finder was Phocylides Holwarda, Professor at the University of Franeker.

Holwarda relates that during the lunar eclipse of 1638, Dec. 10, he observed certain star altitudes at a distance from the horizon, when openings in the clouds afforded an opportunity, and on this occasion "*bis terve in Ceto insolitum quidpiam micare vidisse mihi videbar.*" But being busy with the eclipse, he gave the matter no further attention. But when after several cloudy days he was again observing, for the purpose of correcting certain interchanges in the previously observed altitudes and he again looked in the constellation of the Whale, "*rursus insolitum quidpiam neque aliis temporibus visum unquam in eo micare vidi.*"

He, however, thought it to be a meteor, until he met Bernhard Fullenius the professor of mathematics, who said to him that the star was by him "*perfectissime visum atque observatum.*" He then observed it for position more carefully, and repeatedly, first, apparently, on Dec. 25, O. S. He goes on to say, "As to the time of its appearance and disappearance, I can say nothing absolutely certain. . . . Its magnitude, both to the naked eye and in the telescope, was such as to exceed stars of the third lustre, such as those in the neck and cheek of Cetus, and the knot of Pisces, and sensibly less than stars of the second magnitude, such as the jaw (of Cetus) and the bright one in the head of Aries.

It decreased slowly and gradually until at its heliacal setting it equalled stars of the fourth honor and magnitude."

Holwarda also relates what was known about its re-appearance in 1639 Nov. 7, O. S. as told by Hevel, and after him by Wurm.

Our star was at that time generally held to be a new phenomena, and Holwarda took some trouble to show that his star was not identical with Bayer's o Ceti; especial stress was laid on the fact that Tycho had not observed the star.

Tycho, however, confined himself principally to re-observing the stars of the Almagest, and very seldom observed any others, so that many stars of the 3d and 4th magnitudes are wanting in

his work. In the first years he only observed the principal stars, among which, however, an observation of γ Ceti appears on 1582, Jan. 12. From this date (1582) to 1589, Tycho observed various stars (α, β, η, θ, ι Ceti, α Piscium) in this neighborhood. But if we go forward from Fabricius' maximum, we find that in the years from 1588 to 1591 the star's maxima occurred at the time of year when it is in conjunction with the Sun, namely, in the months from March to June, which explains its absence from Tycho's observations, as it cannot have been noticeably bright at the time of any of them. Only the observation of γ Ceti, 1582, Jan. 12 = Jan. 22, N. S., can have been at a time when, going back from Fabricius' maximum, Mira must have been near maximum. But Tycho was observing γ for a special purpose since he used the star for the determination of his time, and naturally paid no attention to the neighboring stars. The most that can be inferred is, that this maximum was not an especially bright one.

In the following years Mira was observed only by Fullenius and Junge at Hamburg: their very meagre data are to be found in Hevel's *Mercurius*, pp. 148 and 149. Hevel concludes from Fullenius' data, that the latter saw the star in 1642 and 1643; It think (says Argelander) that we can be sure of 1642 only. He says in the letter written 1644, Sept. 10, "*ut et hoc anno, ubi ad hunc usque diem nondum apparuit, quod et annis retro duobus evenit, ubi ante 23 Septembris illum videre non licuit.*"

Had Fullenius seen the star also in 1643, he certainly would not have said "*duobus*," but would have used the expression, "*utroque anno.*"

Really useful observations begin in 1659, when Hevel began his series of observations, which he continued until 1682.

Nearly at the same time with Hevel, the French astronomers began to follow up Mira's variations, first Maraldi, then Bullialdus, Picard, and Cassini. Their observations are much less accurate and numerous than Hevel's, however, and are chiefly useful as a check upon these.

Another observer of this time was Heinrich Syvers in Hamburg. His observations are assembled by himself in a letter to Lubinietski, in the latter's well-known *Theatrum Cometicum*.

A single observation of Huyghens is extant, as follows:

"*1662, 15 Aug. hora 11 1/2 stellam novam in collo Ceti observavi, claritate paene aequalem mandibulæ.*"

The observations of Dr. Gottfried Schulz, of Breslau, in 1696, are very rough, and were discontinued too early for any certain date to be deduced from them.

Then comes a long series of observations of Gottfried and Christopher Kirch, and the wife of the former, Margaretha. The first begin in the winter of 1677-8 and from 1700 forward they go on fairly continuously until 1739. With the exception of the earlier ones, and some of the year 1709, which Bode has published in his *Jahrbuch* for 1821, these have never been published. (Argelander himself gives these observations, 141 in number, extracted by him from the MS at the Berlin Observatory, in detail).

Flamsteed observed the star from 1677 to 1701. Wargentin from 1747 forward. Meyer did not observe it, as at the time when he was observing it was only visible near its minimum phase. Bradley has several estimates of its magnitude, from 1750 to 1759. D'Agelet and Lalande have several observations from 1784 to 1788. These, however, as also Piazzi's, are scattered and not of great value. Herschel, Pigott and Goodricke in England, observed the star from 1777 to 1782. (Perhaps later; Argelander is rather vague here.) Since the year 1838 the star has been much observed, and all the astronomers who have busied themselves with the variable stars have contributed more or less to the available data.

Argelander assembles a list of 77 maxima, extending from 1596, Aug. 13, to 1859. October 10, which he has subjected to a thorough discussion, (Born Observations, Vol. VII, pp. 332-336) and finds elements as follows: Maximum 1751, Sept. 9.76

$$+ 331^d.3363E + 10^d.48 \sin\left(\frac{360^\circ}{11} E + 86^\circ 23'\right)$$

$$+ 33^d.90 \sin\left(\frac{45^\circ}{22} E + 170^\circ 19'\right) + 65^d.31 \sin\left(\frac{15^\circ}{11} E + 6^\circ 37'\right)$$

With his habitual thoroughness, Argelander makes some attempt to deduce a law for the fluctuations of the star's maximum light, but finally comes to the conclusion that the supposed possibly periodical character of this change is not sustained by the observations.

Since the date of Argelander's paper the star has been very faithfully followed up, and maxima have, I believe, been observed whenever it has been practicable; and a mass of observed dates has accumulated, at least equal to the material available for his discussion.

In his Second Catalogue (1874) Schoenfeld gives the same elements, and says in the notes:

"His (Argelander's) elements of maxima still leave outstanding considerable, and occasionally not altogether irregularly occur-

ring residuals. Of the periodic terms, the first is only partially established. . . . The star's intense red color . . . . . causes great personal differences in the estimates of brightness."

Chandler, in his First Catalogue (1888) gives the same elements, omitting the ten-year term. In his Second Catalogue he gives the following formula, the date of the principal epoch corresponding with E 227 of Argelander:

$$\text{Max. 1866 Dec. } 27 + 331d.60E + 25d \sin (4°.5E + 90°) + 25d \sin (1°.125E + 188°.2).$$

In his Third Catalogue (1896) Chandler abandoned for the present the attempt to find a law which should account for the already large discrepancy between the computed and observed maxima, and gives only the date of principal epoch and the mean period, as in the Second Catalogue.

Such is the history of this, the oldest known variable star. For those who are interested in its observation, the following particulars as to its characteristics and peculiarities may be of interest.

Mira is, so far as its light-changes are concerned, a typical long-period variable: the rather rapid increase, less rapid decrease, and slow change at maximum, are all very normal. H. M. Parkhurst finds three strong secondary fluctuations, with amplitudes of a magnitude or more, in the star's light curve about maximum, which he calls maxima A, B and C: my observations of the past two maxima fail to confirm this, showing a normally smooth curve, with no fluctuations beyond the probable errors of observation.

Even for an experienced observer, Mira is difficult of observation, on account partly of its redness, and partly of the inconvenient positions of the comparison stars; estimates made at different hours on the same evening are pretty sure to disagree among themselves, from these causes, and also from the change in the relative apparent positions of the stars, due to changing hour-angle; the best practice is to make a single very careful observation on each evening, using as many comparison stars as can be made available, or, if more than one observation be made, to take the mean of the results.

The light-range is not constant in amplitude, the star occasionally rising to $1^m.3$ at maximum, and sometimes only to $5^m.0$, while the recorded minima range from $8^m.0$ to $9^m.5$. The brightest I have myself seen it was in 1888, when my observations indicate a magnitude of $3^m.1$. It will be seen that while the minima are always telescopic, the maxima may, and generally

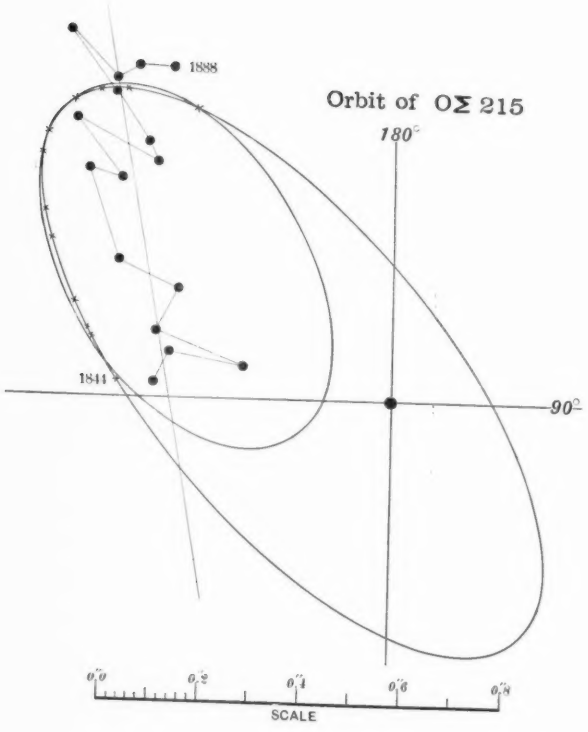
do, call for the opera glass in observing; and, even when the star becomes visible to the naked eye at maximum, its use is advantageous, as it enables the observations to be carried on through the period of bright moonlight, when they would otherwise necessarily be intermitted.

The redness of Mira is often alluded to, and generally exaggerated, in the various accounts of the star. On Chandler's scale of redness, in which a pure red is indicated by 10, the color of Mira is 5.9, according to his observations; which means a reddish orange, quite sufficient to seriously embarrass observation, but by no means the intense nearly pure red of such stars as R Leporis, and RV and RS Cygni, which run from 9.0 to 9.4 on Chandler's scale and affect the eye as being of a nearly pure ruby tint. It seems highly probable that the supposed fluctuations and secondary maxima of this star are largely, if not wholly due to the difficulties introduced by its coloration.

It is often stated that the color of the red stars changes in intensity with the star's change in brightness, being less intense at the maximum, and growing redder at the minimum: this seems to be an illusion, however. Chandler, in his paper above alluded to (*Astronomical Journal*, Vol. VIII, p. 137) found it not to hold true, and my own observations in the same line confirm his conclusions. There is certainly an appearance of such a change, but this is without doubt a purely subjective impression, the impression of the color on the retina being dominated by that of the light as the latter grows in intensity; as it is seen that the ruby shade through which a gas-flame shows pure red, scarcely seems to change the electric arc-light when seen through it.

Very sufficient charts and list of comparison-stars have been given in POPULAR ASTRONOMY for December, 1895. One of the comparison-stars given by Mr. Parkhurst, however, α Piscium, has been stated to be variable by a correspondent of this periodical. The estimates of magnitude for this star, deduced from Argelander's observations of Mira, in which it was used as a comparison-star eighty-one times from 1838 to 1859, are very accordant, showing a magnitude of $3^m.88$ without perceptible change during that entire interval: My own in 1896 are equally accordant, giving a mean of $3^m.85$. As against Argelander's long series, the few discordant estimates of double star and meridian observers are entitled to no weight.

PLATE LII.



THE ORBIT OF *OΣ* 215.

S. W. BURNHAM.

FOR POPULAR ASTRONOMY.

This is one of the close pairs of the Pulkowa Catalogue, discovered by Otto Struve sometime previous to 1843. The measures of this observer commence in 1844 and were continued at intervals down to 1876. It is in the vicinity of the well known star, γ Leonis, about 2° sp, and is No. 3506 of the B.A.C. The components are nearly equal, the magnitudes according to *OΣ* being 7.0 and 7.2. The angular motion is slow in a retrograde direction, with a slow and nearly uniform increase in the distance. The entire angular change between 1844 and 1888 amounts to 52°.

We have one orbit of this system computed by Gore in 1890 from measures down to 1888 (A. N. 2998). From the usual discussion of these observations, he found a period of 107.94 years. While the best possible use may be made of all the material in the way of observations, still it is evident that no reliable result can be reached when the arc described by the companion is so short.

On the accompanying diagram I have given all the observations used in this orbit where both angle and distance were measured. There are other measures made during this interval, prior to 1888, by Dembowski, Perrotin, Schiaparelli, Engelmann, Hall and others which are not given in the list used by Gore. This orbit is shown on the diagram by the larger ellipse. The small crosses represent the corrected positions as given by the computer through which the apparent orbit passes. It will be seen that the distance errors are very large, nine of the sixteen positions being 0″.15 and upwards. It seems very improbable that this should even approximately represent the path of the companion for this interval, to say nothing about the entire uncertainty of the value of the major axis of the apparent ellipse. In fact, this movement can be better explained on the theory of proper motion, by assuming for the companion an annual rectilinear motion of 0″.08 in the direction shown by the right line.

The corrections in angle and distance for all the complete measures used in the computation of the orbit as given in A. N. 2998 will be found in the following table, and also the corrections required upon the theory of rectilinear motion. The position of 1867.20 was erroneously credited to *OΣ*; the measures were made by Dembowski.

	ORBITAL.		RECTILINEAR.		
	°	″	°	′	
1844.54	− 0.1	− 0.07	0.0	+ 0.03	*OΣ*
1848.32	− 0.4	− 0.15	− 2.6	0.00	*OΣ*
1849.04	+ 0.4	− 0.31	− 1.8	− 0.16	*Ma*
1851.34	+ 0.7	− 0.17	+ 1.0	0.00	*OΣ*
1857.34	− 2.1	− 0.27	− 0.6	− 0.05	*Se*
1860.30	+ 1.4	− 0.17	+ 3.3	+ 0.05	*OΣ*
1867.20	− 1.8	− 0.09	− 1.2	+ 0.11	*Δ*
1869.78	− 1.5	− 0.17	+ 1.5	+ 0.02	*OΣ*
1875.81	+ 1.5	− 0.03	+ 4.0	+ 0.08	*OΣ*
1878.07	− 0.2	− 0.17	+ 1.9	− 0.12	*β*
1879.20	− 0.2	− 0.15	+ 1.6	− 0.11	*β*
1881.30	+ 0.3	− 0.01	+ 1.4	+ 0.02	*Je*
1882.27	+ 0.4	+ 0.15	+ 0.7	+ 0.12	*Do*
1882.27	− 0.1	+ 0.02	+ 0.8	− 0.01	*Do*
1882.28	− 3.4	+ 0.01	− 2.5	− 0.02	*Do*
1888.26	− 0.1	+ 0.09	− 3.2	− 0.14	*Sp*

It will be seen that the errors in distance are much less upon the assumption of proper motion, and are only such differences as might be expected in good measures of a pair of this class. They are also much better distributed as to excess and deficiency. The variations in angle are a little larger, but not outside the probable limits of error.

It is extremely probable, to say the least, that these stars form a true physical system. It is a fair inference from the magnitudes of the components, the small apparent distance, and the positions generally as derived from the observations; but beyond that it is impossible at this time to go; and judging from the motion to this time, it will probably be at least another century before the arc is sufficient to give a reliable orbit. According to Porter this star has no sensible proper motion from meridian observations.

The smaller ellipse given on the diagram is merely to show that the computed positions from the orbit referred to can be as perfectly represented for all practical purposes by an ellipse which does not enclose the principal star at all. The difference between this and the orbit found by computation at any of the points derived from the measures is an insensible quantity. The angles are of course identical, and the extreme variation in distance for any position is less than 0″.01. The same observed arc can be passed over in the same manner by a great variety of ellipses, not only between those shown on the diagram, but with much larger major axes, and thus give any eccentricity between zero and unity.

GENERAL PROBLEMS OF CELESTIAL MECHANICS*

Let us now recapitulate what has been said. We have designated the universal validity of Newton's Law of Gravitation as the basis for a true insight into cosmic motions, while at the same time, we have sought in particular, to discover those circumstances which operate against an unobstructed and unlimited reign of this law. In the nature of the case, these considerations, strictly speaking, can refer only to our planetary system. Although it may be scientifically justifiable without hesitation to generalize the experiences made here and to extend their validity to remote stellar spaces, the question whether we have definite indications that the Newtonian forces of attraction are really primary agents with all movements in the remote spaces of the fixed stars, is still not only interesting but of special importance. Such indications can of course be found only in the movements themselves.

For centuries, the fixed stars, as the name indicates, were regarded as absolutely immoveable. That these bodies also show apparent changes of place on the sky, so called *proper motions*, has been known only since the beginning of the last century. These motions are, of course, extraordinarily small and can influence the conspicuous configurations of the constellations perceptibly to the naked eye only after many centuries and even then, only in some specially conspicuous cases. On account of their smallness, these proper motions tell us merely that the star has been displaced, within a certain time, by a small distance on the sky. To decide whether or not this displacement proceeds with exactly uniform velocity, would require a fund of observational material which even in favorable cases, will not be at disposal for centuries.

It is therefore clear that proper motions can denote merely the mechanical condition of the stellar system, which the places and velocities of the individual bodies composing the system give, but can tell us nothing about the forces operating, whose existence is betrayed only in deviations from orbits traversed rectilinearly and with uniform velocity. The case is similar to what we would have, were an observer to view the places and changes of position of the planets for an hour's time. It would indeed be

* Continued from page 481, No. 39.

Address of Professor Hugo Seeliger, delivered on the 28th of March, 1892 at the public session of the Royal Bavarian Academy of Sciences, in commemoration of the 133d year of its founding. Translated by Dr. G. W. Meyers, Associate Professor of Astronomy and Mathematics, University of Illinois.

impossible from the rectilinear displacements thus ascertained, to form any conclusions concerning the connection which binds the single planets together. A proof of the validity of Newton's law is accordingly at present not derivable from proper motions.

This is however made possible by means of other phenomena in the sky. About the middle of the preceding century astronomers became aware that two or more stars are to be found in extreme nearness to each other much more frequently than is to be expected. When, later, William Herschel instituted a systematic search for double and multiple stars and discovered several hundred such bright pairs, which were in part so close as to be distinguishable only by his most powerful optical means it became even then, quite well established that most of these pairs represent physically connected systems whose motions about each other are governed by forces of attraction. But it was moreover, the work of Herschel which raised the correctness of this view above all reasonable doubt. When after the lapse of two decades he re-investigated the doubles he had discovered, he was able to recognize in many cases quite a distinct, and in a considerable number of cases a very significant rotation of the line connecting the components.

This department of stellar astronomy has been greatly developed since then. We are now acquainted with several thousand double and multiple systems whose physical connection is undoubted. In case of several dozen, a complete revolution of the components about each other has either been observed or the period of such revolution can be computed with a high degree of certainty. We have here at disposal those very phenomena in great abundance, which evaded us in case of stellar proper motions. By a change in the subject matter of investigation from rectilinear deviations of position to orbits of distinct curvature, a foundation has been given to mathematical calculus and the last decades have produced a remarkable number of detailed investigations in this direction. All these have furnished proof, undoubtedly within proper limitations, that the components of binary stars in reality mutually attract each other according to Newton's law and consequently that their components describe elliptical orbits about each other.[1]

[1] This notion is of course to be kept within proper limitations, as I have expressly stated in my second treatise concerning the multiple system ζ Cancri page 9 (Abhandbungen der k. bayer. Akadamie die der Wiss II Cl. XVII Bd. I Abth. 1888), "It seems to me that the low degree of accuracy of double star measures as well as the shortness of the time over which they extend by no means warrant the degree of certainty with which it is maintained by some that the double star

Since as yet, there is no reason to think these systems nearer us than other equally bright stars, we are now practically certain that the attraction of masses according to Newton's view is the fundamental law for all motion whether it be in the remote interstellar spaces or within our planetary system. But there still remains to be spanned the wide abyss separating us from those remote double systems. Do attracting forces operate also in these immeasurable spaces? is the present form of the question. One might perhaps be inclined to answer this question unconditionally in the affirmative upon the basis of facts already adduced. A doubt in the matter however is, not only permitted but it is even necessary to emphasize such doubt. At all events the matter appears to be so far cleared up as to justify us considering the assumption of the universal validity of Newton's law as an extremely probable hypothesis.

Although we must at present put aside the idea that on the basis of this hypothesis the entire stellar complex visible to us is to be regarded as a mechanical whole, and though we must leave the solution of this greatest and most important problem of astronomy to future generations on account of a lack of the necessary data of observation, there is notwithstanding a natural necessity for forming notions of some sort concerning the external relationships of the stellar system to which we belong. Such attempts have been made in great number. In most of them unfortunately, there has not been exercised sufficient caution to prevent the formation of wholly groundless phantasies. If Kant located the centre of the stellar system of the universe in Sirius, Lambert in the Orion nebula and Maedler on the basis of numbers falsely understood in the Pleiades, we are justified in designating such statements as incautious, to say the least. Nothing can be said to their favor while much may be urged against them.

When we consider the countless stars of the firmament and recognize with astonishment that the number of these luminous suns rises to the infinite; when we arm the eye with telescope and learn that the increase in their number appears to approach no limit whatever even when the giant telescopes of the present day

orbits heretofore computed have furnished proof of the validity of Newton's Law of Gravitation in those remote celestial spaces. But even without these computations, no one would have doubted that the law mentioned was applicable on the whole to the fixed stars. It is a question of small deviations which perhaps are yet to be ascertained. The extent of these deviations, however, would produce even now in the planetary system a complete discord between theory and observation; but it is completely masked by the inaccuracies attaching at present to double star measures. By this remark it is not at all to be asserted as probable that even demonstrable deviations from Newton's law actually exist."

are called into requisition; and especially when we reflect upon the tremendous distances which separate us from the fixed stars, of which distances recent astronomy permits an estimate and to traverse which light itself must consume many, aye even hundreds of years; certainly the Earth, the Sun and even the planetary system itself must shrink to such relatively contracted dimensions that any thought of claiming for our abode any specially favored part of space, or of our solar system assuming a special and dominating position among the starry multitude, cannot be entertained for a moment. Such a notion belongs to an era of human thought, happily long since passed, whose chief characteristics were bigotry and *naiveté*. We are in point of fact, compelled to contemplate the universe from a position favored in no sense whatever. This position is, like every other star's position, rigorously subject to the general laws of motion. It moves forward in space with a velocity which we know both in magnitude and direction. But this motion must be revealed in the stellar proper motions, because they occasion an apparent displacement of the stellar places. Traces of such displacement have indeed, for a long time, been observed. As early as the beginning of the present century, it had been learned that stellar proper motions show in one direction a close conformity to law despite the confusedness they exhibit at first glance; and this inference has been confirmed by many recent investigations.

Those stars situated in the region of the constellation Hercules seem on the average, to be withdrawing from one another and this withdrawal diminishes with increasing distance from this region; whereas in that part of the heavens directly opposite, a contraction of their distances is plainly manifest. It is not necessary to go far to connect this phenomenon with a very familiar experience of daily life. To a traveller approaching a wood the trunks of the trees seem to widen out from each other. They appear to increase their mutual distances, and the converse occurs as the observer recedes from the wood. For both these phenomena, for the last named experience of daily life as well as for the more hidden one which has been revealed only after decades of experienced observation, there is one and the same explanation. Consequently nothing can unsettle the conviction that at present our solar system is approaching the stars in Hercules. But any attempt to draw more than this from the facts just mentioned can be carried out only at the expense of truth. And it is especially clear that this motion of the solar system need not in any way be connected with its progressive motion through space,

just as our approach to, or withdrawal from, the wood has nothing at all to do with our motion through space and hence seen from the Sun would be wholly inconsequential in comparison with the entire motion of the Earth. Moreover it is well to consider that the motion of the solar system has been derived only from the apparent shifts of position of the nearer fixed stars. It is possible, perhaps even probable, that the latter may in general, traverse space in conjunction with the Sun and that only relatively small deviations in the one direction or the other can occur.[1] It is then clear how important a knowledge of the proper motions of the fainter stars may be, as bearing upon this and similar questions. But the attainment of this knowledge lies at any rate in the remote future and there must elapse between now and then many centuries of observational activity. Fortunately astronomy has only temporarily and in our time never, been wanting in energetic and unselfish devotees, who while laying the basis of later discoveries, found their chiefest satisfaction in taking upon themselves the collection of data of observation in themselves uninteresting and unprofitable. The present generation has in fact, done very much in this self-denying sphere of activity.

The beautiful exemplification of a sacrifice in the highest degree worthy of humanity because foreign to vanity in every form, has been realized in this field of activity. May succeeding generations not forsake the toilsome path already begun, but remain courageously upon the way, which for the present offers but little prospect, but which will surely lead at last to the hoped-for eminence from whose serene summit the outlook will be broad and in every way amply remunerating to all efforts of sacrifice bestowed in its attainment.

[1] In a pamphlet of unusual merit and characterized by acute perception on its author's part and entitled "The Historical Development of the Idea of Motion, etc., Leipzig 1886," Mr. L. Lange has shown that the true nature of relative motion has in the problem of the Sun's motion very frequently, perhaps usually, been incorrectly understood. In all fundamental questions, in so far as they concern this problem, we unhesitatingly agree with him and I have expressly done so in an article in the "Viertaljahrsschrift der Astron. Gesellschaft," for 1887. Though I there expressed the opinion that perhaps most of the astronomers, treating the problem of the Sun's motion, had a proper conception of the matter, yet out of certain more recent articles, well-grounded doubts in this matter have arisen in my mind. But this is not the place to enter upon an investigation of these things whose settlement would involve a lengthy discussion. The reader needs here only to be reminded of the importance of the confirmation of the motion of nebulæ in the line of sight which has recently been undertaken with such flattering promise. If these objects are really wholly without our stellar system, a displacement with reference to them, would show quite different results provided the Sun and the nearer fixed stars have an appreciable common velocity. There is therefore the possibility of arriving at very valuable information concerning the motion of the solar system and also concerning the position of nebulæ with reference to the stellar systems.

THE STUDY OF PLANETARY DETAIL.

T. J. J. SEE.

For Popular Astronomy.

The study of planetary detail in the modern sense of that term is the newest of the branches of astronomy; in the older and more restricted sense it dates back to the time of Huyghens, Miraldi and the Cassinis, and is thus almost as old as the invention of the telescope. In the seventeenth and eighteenth centuries, however, the telescopes were so imperfect, of such unwieldy form and so clumsily mounted that only the roughest study of delicate phenomena was really possible. After the great improvement of the reflector by Sir William Herschel, he and other observers made conspicuous advances in many lines, but the finest work on very delicate objects could not be done before the introduction of equatorial mounting with clock-work, the optical improvements effected by Frauenhofer, and the much more extensive progress in the same direction by the Clarks, who have brought telescope-making to its present well-nigh perfect state.

Galileo began the telescopic exploration of the heavens, and very naturally gave his attention to every class of celestial phenomena of real interest. Thus, he investigated the phases of Venus and Mars, the rings of Saturn, the satellites of Jupiter and the changes in brightness which they undergo in the course of their revolutions. In his earliest explorations he thus displayed the same spirit of inquiry which has characterized the subsequent development of modern physical science. For him, as for Darwin in natural science, nothing was too small for careful study; he realized that from inconspicuous phenomena the greatest discoveries frequently arise.

As Astronomy has grown, it has developed into a dozen branches and the great scope of each branch has naturally prevented the majority of astronomers from mastering more than one, or at most, two branches of the science; there has thus arisen an enormous specialization and unfortunately it has been carried so far that in many cases there is a lack of liberality in assigning credit and reality to achievements in other lines.

For example, a man who has long devoted his whole attention to determining the positions of the fixed stars may easily come to think that star-cataloguing is the sum and substance of astronomy; and it is unquestionably a necessary foundation for all

thorough study of the structure of the heavens, the constants of astronomy, and the relative motions of objects projected on the surface of the celestial sphere.

Another astronomer who has consecrated the labors of a life time to the abstruse studies of celestial mechanics (for which the writer has great admiration) may feel that the planetary theories, and the writings of Newton and Laplace are the only really solid parts of the temple of astronomical science; they are indeed the foundations of that sublime structure, and just as essential to it as the cataloguing of the fixed stars. Still another who has devoted the principal efforts of his life to micrometrical measurement, say of double stars, satellites and comets, or to the spectroscopic and photographic branches of astronomy, may think that in these lines are centered the principal interests of the science. Such are the actual views of specialists, but when we contemplate the subject philosophically and survey the domain of science in its vast extent and historic perspective, we must admit that these views are narrow and ungenerous. We may, perhaps be excused for entertaining such views when we are stirred by enthusiasm, or when we desire to stimulate effort along certain lines; but to entertain them calmly and seriously would be a sure sign of narrow-mindedness. In the course of time all branches of the science are found to be important, though perhaps not equally important; nothing in the way of faithful observation of the phenomena of the physical universe is without value; and frequently that which appears the least important in one age will appear the most important in the next.

In the century following Newton the theory of gravitation was the principal object of attention; in the century following Lalande, Bessel and Argelander the cataloguing of the fixed stars on an extensive scale has been pushed vigorously forward; and now within the last thirty years the work of spectroscopy and photography has come to claim a great part of the energy of astronomy. It seems to be assumed by many that the subjects which are cultivated by the majority are those which will yield the greatest discoveries. Nothing could be more erroneous. In fact it is generally the subjects which lie outside of the beaten track, and are either inaccessible to the multitude or too difficult for them, that yield the really great advances in knowledge. Nor is it a matter of much consequence whether discoveries are recognized by the contemporaries of the discoverer. Newton's theory of gravitation was not adopted in France till the time of Clairaut, Euler, Lagrange and Laplace, but the incomparable de-

velopments of these great men have made adequate amends for the blindness and incompetency of Newton's contemporaries. The multitude cultivate only the commonplace and the orthodox subjects, and orthodoxy in science is as little entitled to admiration as it is in party politics.

It may well be doubted whether the photographic chart of the heavens, to which many observatories are now devoting their attention to the exclusion of everything else, will ever yield the golden prize expected of it; but this great undertaking will undoubtedly have some value, and perhaps even a high value.

The study of planetary detail is now pressing rapidly to the front, and although by no means an orthodox subject, it is engaging the attention of several good telescopes and of many energetic observers. The field is almost new, and great possibilities are opened for those who first occupy the ground and cultivate it vigorously. To determine the nature of the surface markings of the planets, the changes they undergo, and the causes by which the changes are produced are the principal objects of study.

The study of detail on the lunar surface has long since been practically concluded by the labors of a dozen celebrated artists. Even if the work of Beer and Mädler, Nasmyth and Carpenter, and Schmidt was not entirely exhaustive, the modern photographic work of Draper and Rutherford, Puiseux and Loewy leaves practically nothing for exploration.

The scientific study of Mars, our next nearest neighbor in space, on a modern basis, was begun by Schiaparelli in 1877; the great discoveries which he made during the next few years have at last been duly recognized, after years of incredulity; and during the past six years many observers have given some attention to this interesting planet, while a few have studied it with extreme care and regularity. The problem at present is not merely to map the general features and to find the period of rotation, but to investigate all the changes on the planet's surface produced by atmosphere, meteorological, climatic, vegetable or animal agencies.

The second observers to vigorously undertake this work were Professor Pickering and Mr. Douglass of the Harvard station in Peru, during the opposition of 1892. It was there that Mr. Douglass first noticed the canals in the dark regions, first recognized and systematically studied by him two years later, and the phenomenon of projections on the terminator, which were subsequently much more carefully investigated at Flagstaff during the

opposition of 1894. It is well known that these terminator observations at the Lowell Observatory have established the existence of clouds in the Martian atmosphere, and enabled the astronomers to draw important conclusions regarding the meteorology of Mars, which is now admitted to be a desert planet. The energy with which these new phenomena have been observed by Mr. Lowell, Professor Pickering and Mr. Douglass, is fairly commensurate with the general interest of the subject, and from their labors we may some day expect a knowledge of climatic conditions in the only other planets at all resembling the Earth.

Now that so much has been done, in the way of hundreds of drawings, by different observers, under conditions as independent as possible, with results in substantial agreement, it is at last admitted that Mars has canals, and even that they are double. More than this, it is now recognized that the manner of the arrangement of the canals is very remarkable, and that the planet is covered with an abundance of inter sections called "oases." Thus all the principal phenomena observed on the planet are gradually being confirmed as realities, and are taking their places among the legitimate objects of astronomical attention.

But it is singular to observe with what incredulity these first announcements were received. A certain authority of great celebrity, say, in the theory of gravity, did not credit the existence of these objects, though he had never examined Mars with any continuity, either with good or bad seeing; ergo the canals are probably only imaginary, and really do not exist! It is unnecessary to comment on the more sensible attitude of Otto Struve, who when unable to confirm Schiaparelli's discoveries, doubtless owing to climatic conditions at St. Petersburg, said: "I am sorry to say that I have never been able to see the canals, but knowing M. Schiaparelli's excellence as an observer, I cannot doubt that they are there."

Since Aug. 1, 1896 the writer has had a number of occasions for examining Mars by the courtesy of his colleagues engaged in this work; and although he had never formed any very definite opinion prior to this date, he has been simply astonished by the amount of detail shown, when the seeing is really good. The Canals are not only very plain, but are also not infrequently double, and are seen to constitute a wonderfully complex system. The polar caps are perfectly distinct, and present a striking resemblance to the snow on the summits of the rugged San Francisco mountains at Flagstaff. We give herewith some illustrations which may interest those who care to see how Mars looks

to a layman, whose specialty is in another line. I ought to add that in no case have I consulted the maps of the planet or the drawings of my colleagues; but every feature sketched has been observed in entire ignorance of how the phenomena ought to appear. When working with my associates it was my invariable custom to carefully exclude all view of their drawings, lest an inspection of their work might give an unconscious bias to my judgment. The drawings are therefore as independent as it is possible for any scientific work to be; but of couse they can not have the same claim to completeness which could be made for work of observers who have devoted years to this special subject. It is probable that many phenomena distinctly visible under the best conditions have been entirely overlooked.

No. 1 represents one of my earliest sketches; the seeing was noted at six, ten being perfect but never realized in practice. The time is seven hours slow of Greenwich.

No. 2 and the other four sketches were made at Mexico, where we use local time, $6^h\ 36^m$ slow of Greenwich.

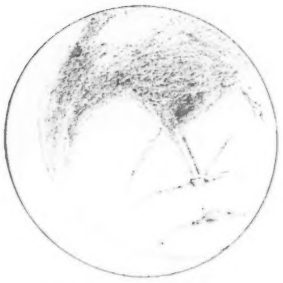
Sketch No. 4 shows the first canals in the dark regions which I was able to recognize; others were seen in sketches 5 and 6. No. 5 is very interesting as showing the Eumenides closely double; the other large double canal has not been identified with certainty. No. 6 shows the Syrtis Major with its principal features, including the three canals by which it is traversed.

With regard to Mercury and Venus, in the study of which Mr. Lowell has recently achieved such important results, I may add that on a number of occasions I have seen the markings and made drawings of their principal features. Those on Mercury were perfectly distinct the first time I ever examined the planet, and remain impressed upon my memory to this day. Those on Venus are somewhat less distinct, but yet perfectly clear when the seeing is good. The accompanying illustrations show what has been seen by the writer when he has made rather casual but yet careful observations of these planets.

In this connection I wish to emphasize what has so often been mentioned by others, namely, the supreme importance of good atmosphere. The best telescope in the world will show next to nothing when the seeing is bad; the difference in the markings on different nights, when the seeing has become deteriorated from atmospheric causes can hardly be appreciated except by those who have actually worked on delicate phenomena requiring a clear and steady definition. Though I have never made very prolonged observations at different places, I have done work which

PLATE LIII.

No. 1.



1896, Aug. 17, $16^h\ 40^m$.
Seeing 6. $\lambda = 41°$.

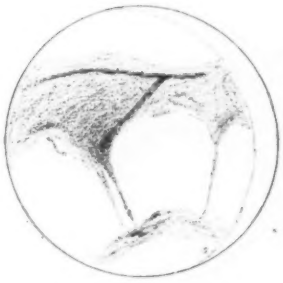
No. 2.

1897, Jan. 9, $8^h\ 10^m$.
Seeing 4. $\lambda = 20°$.

No. 3.

1897, Jan. 27, $7^h\ 35^m$.
Seeing 6. $\lambda = 206$.

No. 4.

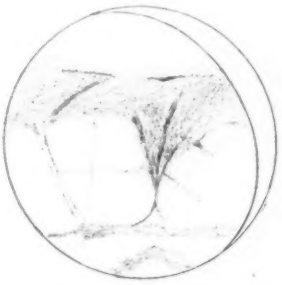


1897, Feb. 13, $6^h\ 50^m$.
Seeing 5. $\lambda = 37$.

No. 5.

1897, Feb. 24, $5^h\ 10^m$.
Seeing 6. $\lambda = 269$.

No. 6.

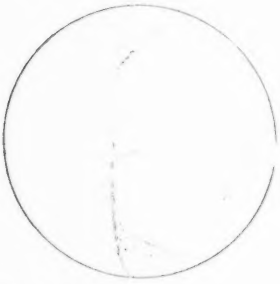


1897, Feb. 24, $6^h\ 15^m$.
Seeing 6. $\lambda = 285$.

DRAWINGS OF MARS BY T. J. J. SEE.

PLATE LIV.

No. 1. MERCURY.

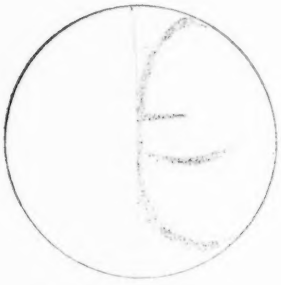


1896, Oct. 28, 0^h 0^m.
Seeing 3.
By W. A. Cogshall.

No. 2. MERCURY.

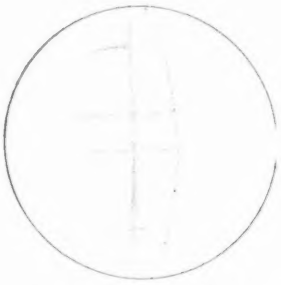
1897, Jan. 4, 5^h 26^m.
Seeing 3.

No. 3. MERCURY.



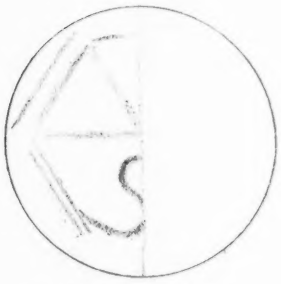
1897, Feb. 13, 23^h 16^m.
Seeing 4.

No. 4. VENUS.



1897, Jan. 4, 5^h 43^m.
Seeing 2.

No. 5. VENUS.



1897, Feb. 18. 3^h 23^m.
Seeing 2.

No. 6. VENUS.

1897, Feb. 24, 3^h 26^m.
Seeing 4.

DRAWINGS OF MERCURY AND VENUS BY T. J. J. SEE.

enables me to estimate the seeing at Berlin, Cambridge (England) Cambridge, Mass., Charlottesville, Va., Chicago, Madison, Columbia, Mo., Flagstaff, Arizona, and Mexico; and I do not detract in any way from the merits of the places where I have formerly observed when I say that the seeing at Flagstaff is by far the best I have seen. Indeed it is probably the best to be had in the northern hemisphere, on account of the peculiarly favorable situation at a high altitude, in the midst of a small pine forest surrounded by desert for several hundred miles in all directions.

A good many persons make the mistake of supposing that because they do not credit a given announcement, it is not to be accepted until confirmed by some other "keen-sighted observer." It is generally recognized that there is no great difference in the sensitiveness of the normal human eye; on the whole it may be assumed that a person otherwise highly intelligent will have "keen sight" (unless the eyes are physically defective). A good deal of advantage is acquired by training and experience in a given line of observatorial work, but no sane person will suppose that nature has given certain persons a monopoly of vision. The important thing in all astronomical work is a faithful delineation of the facts revealed by the telescope; if those now living fail to accept things which run counter to their preconceived notions it is a matter of small consequence. Posterity will be able to decide whether persons inclined to discredit observations on the simple ground of prejudice are in any way superior to those in past ages who for similar reasons have persisted in living behind and in ignorance of some of the most important advances of their times.

LOWELL OBSERVATORY, City of Mexico,
Feb. 20, 1897.

A GREAT CIRCLE ON THE CELESTIAL SPHERE.

ORRIN E. HARMON.

FOR POPULAR ASTRONOMY.

Finding the position of a great circle on the celestial sphere, with respect to the horizon and meridian, is a problem of some importance in practical astronomy. With a celestial globe, this position is easily found, if the circle is marked on the globe. Not every one, however, owns such a globe, nor is it always accessible to the student of astronomy.

A little mathematics enables one to calculate the position of a great circle with reference to the horizon and meridian, and it is often convenient to know this position. The question is not a new one, although the formulæ necessary to make such a calculation are not generally given in works on practical astronomy. Solutions of so simple a problem have undoubtedly been rendered, but the writer has not seen them. It is the object of this article to develop the formulæ required for the solution of the problem, to discuss their meaning, and to determine the elements of a great circle on the celestial sphere, in all their generality.

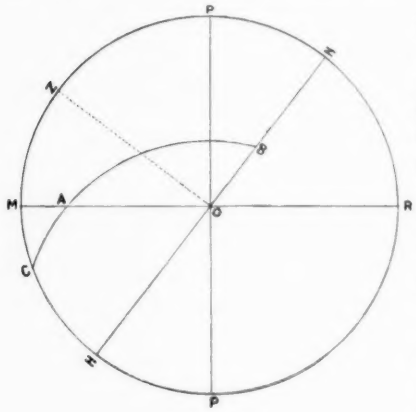


FIG. 1.

Here is a figure familiar, in its main construction, to every student of astronomy. The circle $PMP'R$ is a celestial meridian, MOR the celestial equator, HN the eastern half of the horizon, whose zenith is Z. PP' are the celestial poles—P the north pole, P' the south pole. O is the eastern point of the horizon, and ZO the prime vertical. Now let a great circle of which CAB is a part, intersect the meridian at C, the equator at A, and the horizonat B.

For a given place, the horizon and meridian remain in a constant position. Also the celestial equator, though partaking of the diurnal motion, is inclined to the horizon at a constant angle. Remembering these points, and keeping in mind the elementary geometrical principle that all great circles bisect each other, let us first examine the position of a great circle with respect to the celestial equator.

It follows that one-half of such a circle lies north of the equator and one-half south of it. The crossing points on the equator pass under the general name of "nodes." The point where the circle crosses from the south to the north side of the equator is the ascending node, and the point where the circle crosses from the north to the south side of the equator is the descending node.

In figure 2, EW represents the celestial equator. AND is the north half of a great circle with the ascending node at A. DSA is the south half of the circle with the descending node at D. The

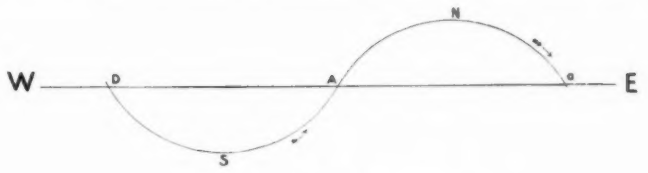


FIG. 2.

angles at A and D measure the inclination of the circle to the equator; and calling the angle of inclination at A *positive*, the angle of inclination at D is *negative*. The nodes at D and A are 180° apart; and unless they happen to lie in the horizon (in which case they are at the east and west points) one node must always be *above* the horizon. So also one-half of every great circle, except the horizon, must always be *above* the horizon.

Returning to figure 1 the ascending node is above the horizon and is east of the meridian. CM is the declination of the crossing point on the meridian, and ZC the zenith distance of the crossing point. The angle at C measures the inclination of the great circle to the meridian, and the angle at B measures the inclination of the circle to the horizon. The arc BN measures the azimuth, and the arc BO the amplitude of the point where the great circle cuts the eastern horizon. Of course the azimuth and amplitude are the same on the western horizon.

As above remarked, the celestial equator remains at a constant inclination to the horizon, notwithstanding its diurnal motion. This inclination is the angle MOH, which is the complement of the latitude, ZOM. The equator, however, by the diurnal motion, carries every great circle, except the horizon, meridian, prime vertical and six o'clock hour circle (POP') into an ever shifting position, with reference to the horizon and meridian. Now let us examine figure 1 and determine the formulæ required for the solution of our problem.

The triangle AMC is spherical and right angled at M. Then we have tang. MC = sin MA tang. MAC. MC is the declination of the crossing point on the meridian; denote by D. MA is the hour-angle of the node from the meridian; denote by H. MAC is the angle of inclination of the great circle to the celestial equator; denote by I. Then tang. D = sin H tang. I, a formula which gives the declination of the crossing point, C.

Also from the same triangle we have cos ACM = cos H sin I, a formula which gives the crossing angle on the meridian at C.

The sperical triangle BHC is right-angled at H. Then

cos B = sin Z sin C—remembering CH is the compliment of CZ, the zenith distance of C. In the last formula Z denotes the zenith distance of C.

Finally we have tang. BH = cos Z tang. C; or tang. azimuth = cos Z tang C. Then since BO is the compliment of BH, cot amplitude = cos Z tang C.

These formulæ determine

1. The declination of the crossing on the meridian, D.
2. The angle of such crossing point, C.
3. The inclination of the great circle to the horizon, B.
4. The amplitude of the points where the circle cuts the horizon, A.

Since the hour-angle of a heavenly body is equal to the sidereal time minus the right ascension of the heavenly body, it follows that the primary elements necessary to the calculation of the above formulæ are:

1. The inclination of the great circle to the equator.
2. The right ascension of the nodes.
3. The day of the month and time of day.
4. The latitude and longitude of the place.

Arranging the above formulæ in order, we have:

$$\begin{aligned} \text{tang } D &= \sin H \text{ tang } I && (1)\\ \cos C &= \cos H \sin I && (2)\\ \cos B &= \sin Z \sin C && (3)\\ \cot A &= \cos Z \text{ tang } C && (4) \end{aligned}$$

In formulæ (1) and (2), H and I are the necessary elements; in formulæ (3) and (4) Z and C are the necessary elements.

When the declination, D, of the crossing point, C is known, the zenith distance is easily found, for it is equal to the latitude minus the declination.

In the above rule for finding the hour angle, it is clear that when the node is west of the meridian, H is positive; when the node is east of the meridian, H is negative.

We are now prepared to discuss the above formulæ.

In formula (1), D is positive if sin H and tang I have the same sign; D is negative if they have opposite signs. That is, the declination of the meridian crossing point is *north* in the former case, and *south* in the latter.

If H and I are both positive, the ascending node is above the horizon and the hour angle is west; if H and I are both negative, the descending node is above the horizon and the hour angle is east.

In formula (2), since C is determined by the cosine, the angle of inclination to the meridian is less than 90° if cosine C is positive; but greater than 90° if cosine C is negative. Cosine H is positive, whether H is positive or negative; and since H can never be more than 90°, the positive or negative character of sin I will determine the limit of C.

In formula (3) cosine B will always be positive since sin Z and sin C are always positive.

In formula (4) cot A will be positive if cos Z and tang C have the same sign; negative if they have opposite signs.

If Z and C are each less than 90°, or each greater than 90°, cot A is positive. If one is greater than 90°, and the other less than 90°, cot A is negative. When cot A is positive, the great circle cuts the horizon at points between N and E, S and W. When cot A is negative, the great circle cuts the horizon at points between S and E, N and W.

Here we may remark that the amplitude is considered positive when it is reckoned from E toward N, or from W toward S. The amplitude is negative, when it is reckoned in the opposite direction.

It will be noticed that when I is positive—that is, when the ascending node is above the horizon—the amplitude is positive, unless the zenith distance is greater than 90°.

When I is negative—that is, when the descending node is above the horizon—the amplitude is negative, unless the zenith distance is greater than 90°.

Hence the ascending node above the horizon gives what may be termed the positive position of the circle; the descending node above the horizon gives the negative position of the circle.

Let us notice how these formulæ determine the position of the circle when the nodes are in the horizon. H is always negative in this case, because reference is made to the node that is about to rise above the horizon; and this of course, must be the eastern node. Then sin H always equals -1, for $H = -90°$. When the ascending node is in the eastern horizon, I is positive; hence from formula (1) tang D is negative and the declination is south. If the descending node is in the eastern horizon I is negative and tang D is positive, and the declination is north. This shows that the sign of the declination takes the contrary sign of the rising node.

Also in formula (2), cos H in this case $= 0$. Hence cos $C = 0$, and $C = 90°$. When $C = 90°$, sin $C = 1$. Then formula (3) gives cos $B =$ sin Z; that is the inclination to the horizon is the complement of the zenith distance—a conclusion manifestly true.

When $C = 90°$, tang C is infinite. Hence cot A is infinite and $A = 0$; that is the nodes are in the east and west points of the horizon. This result gives the supposition in the last case—that is, that the nodes are in the horizon.

We are now prepared to apply the above formulæ in some practical problems. The most simple application is in the case of the ecliptic. Put the problem in this way:

What is the position of the ecliptic May 20, 1895, at 9 o'clock P. M. at a place in latitude 47° N. and longitude $8^h\ 11^m$ W?

Here $I = 23°\ 27'$, and the right ascension of the nodes is 0^h and 12^h.

The sidereal time corresponding to 9 P. M. for the above date and place is $12^h\ 54^m\ 21^s$. Since the R. A. of the descending node, or autumnal equinox is 12^h, the sidereal time minus the right ascension is $54^m\ 21^s = 13°\ 35'\ 15''$. This shows that the node is west of the meridian and therefore the hour angle H is $+ 13°\ 35'\ 15''$. Here I is negative. Then from formula

(1). tang D = sin H tang I.

$$\log \sin H = 9.370939$$
$$\log \tan I = 9.637265n$$

$$D = -5°\ 49'\ 10'' \therefore \log \text{tang } D = 9.008204n$$

Hence the declination of the meridian crossing point is south.

Formula (2) gives us cos C = cos H sin I.

$$\log \cos H = 9.987671$$
$$\log \sin I = 9.599827n$$

$$C = 112°\ 45'\ 20'' \therefore \log \cos C = 9.587498n$$

Formula (3) gives us cos B = sin Z sin C

$$Z = 47° - (-5°\ 49'\ 10'') = 52°\ 49'\ 10''. \qquad \begin{matrix} \log \sin Z = 9.901314 \\ \log \sin C = 9.964808 \end{matrix}$$

$$B = 42°\ 43' \therefore \log \cos B = 9.866122$$

Formula (4) gives us cot A = cos Z tang C.

$$\log \cos Z = 9.781273$$
$$\log \tan C = 10.377321n$$

$$A = 34°\ 46' \therefore \log \cot A = 10.158594n$$

The cot of A being negative, the amplitude is 34° 46′ S of E and N. of W.

Arranging these results in order

$$\begin{matrix} D = & 5° & 49' & 10'' & \text{south} \\ C = & 112 & 45 & 20 & \\ B = & 42 & 43 & & \\ A = & 34 & 46 & & \text{S of E and N of W} \end{matrix}$$

These figures locate the ecliptic with reference to the horizon and meridian with great exactness.

The Milky Way affords another application of these formulæ. The central line of the Milky Way is quite nearly a great circle whose ascending node is in R. A. 7^h and whose descending node is in R. A. 19^h. The inclination of the Milky Way to the celestial equator is about $63°$.

Required the position of the Milky Way for May 20, 1895 at 9 P. M. for latitude $47°$ longitude $8^h\ 11^m$ W.

The sidereal time, as in the former problem is $12^h\ 54^m\ 21^s$. The R. A. of the ascending node is 7^h; hence the hour angle is $5^h\ 54^m\ 21^s$ west. Consequently the nodes are quite nearly in the horizon. The south half of the Milky Way must therefore be below the horizon, as the horizon itself has an inclination to the celestial equator of $43°$.

Let us take another problem of the Milky Way, for a different date.

Required the position of the Milky Way, December 10, 1895 at 9 P. M. for latitude $47°$ N, longitude $8^h\ 11^m$ W.

The sidereal time is.....	2^h	18^m	39^s
R. A. ascending node...	7	00	00
Hour angle is.....	4	41	21 east

and $H = -\ 70°\ 20'\ 15''$.

Following the formulæ in regular order we have

$$H = -\ 70°\ 20'\ 15'' \quad \therefore \log \sin H = \ \ 9.973909n$$
$$I = +\ 63° \qquad\quad \therefore \log \tan I = 10.292834$$
$$D = -\ 61°\ 35' \qquad \therefore \log \tan D = 10.266743n$$

For formula (2)

$$\log \cos H = 9.526957$$
$$\log \sin I = 9.949881$$
$$C = 72°\ 33' \ \therefore \log \cos C = 9.476838$$

$Z = 47° - (-\ 61°\ 35') = 108°\ 35'$, which shows that the Milky Way cuts the meridian *below* the south point of the horizon.

For formula (3)

$$\log \sin Z = 9.976745$$
$$\log \sin C = 9.979539$$
$$B = 25°\ 17' \ \therefore \log \cos B = 9.956284$$

For formula (4)

$$\log \cos Z = \ \ 9.503360n$$
$$\log \tan C = 10.502601$$
$$A = 44°\ 36' \ \therefore \log \cot A = 10.005961n$$

Therefore the Milky Way cuts the horizon 44° 36′ S of E and N of W. Then we have

$$D = 61° 35' \text{ S.}$$
$$C = 72 \ \ 33$$
$$B = 25 \ \ 17$$
$$A = 44 \ \ 36 \text{ S of E and N of W}$$

Applying these formulæ to the Moon's path, we have I equal to the Moon's highest declination, N and S for the month; and the right ascension of the nodes can be easily computed from the data given in the *Nautical Almanac*. The foregoing problems, however, sufficiently illustrate the application of the formulæ, and show how elegantly the science of trigonometry applies in the solution of the practical problems of astronomy.

CHEHALIS, Lewis Co., Wash.

EVENINGS WITH THE STARS.

MARY PROCTOR.

FOR POPULAR ASTRONOMY.

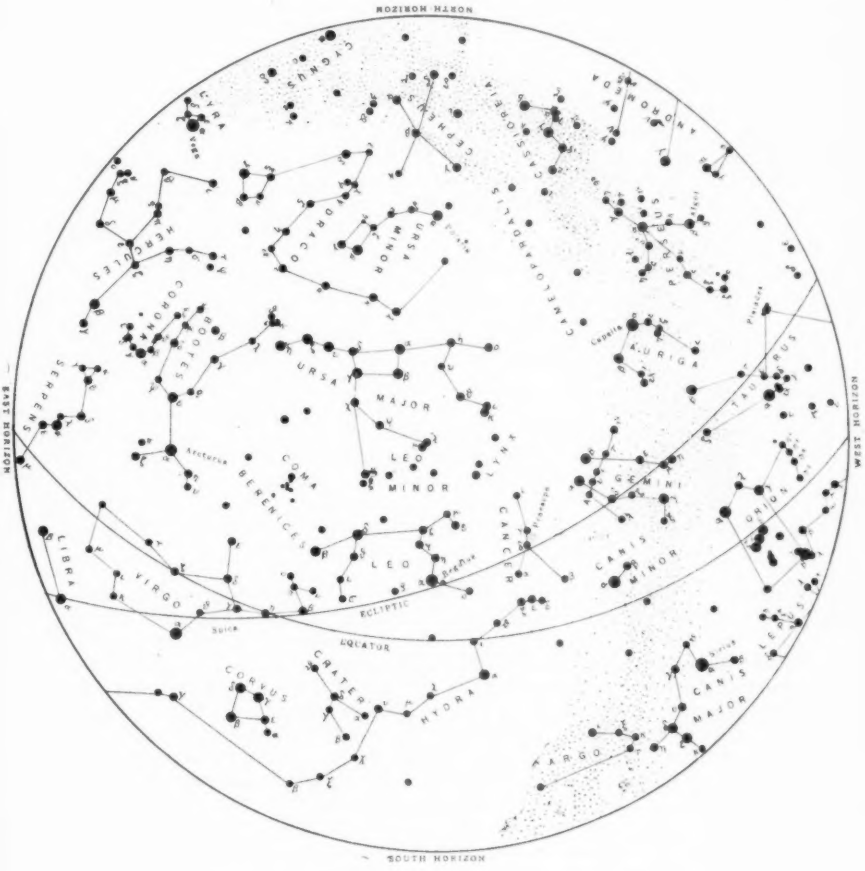
During the month of April, the Great Bear (*Ursa Major*) is nearing the point overhead, the Pointers aiming at the Pole Star (*Polaris*) and (*Draco*) the Dragon curves between the Pointers and the Little Bear (*Ursa Minor*), then back towards Hercules. The bright eyes of the Dragon are rather low down, being north of northeast. *Cepheus* is due north, with *Cassiopeia* on his left, and *Andromeda* just setting, almost due northwest. Above her is the *Camelopard*. *Perseus* is in the northwest, rather low, and higher up on his left is (*Auriga*) the Charioteer. Between west and northwest is (*Taurus*) the Bull, with its ruddy eye *Aldebaran*, and the silvery cluster of the *Pleiades*. The Twins, (*Gemini*) are in the mid-heavens, due west, with the Little Dog (*Canis Minor*) on their left, (*Cancer*) the Crab above, and (*Canis Major*) the Greater Dog beneath, chasing the Hare (*Lepus*) below the horizon. The Great Ship (*Argo*) is setting in the south. Between the southeastern horizon and mid-heavens, the Sea Serpent (*Hydra*) shows its full length, rearing its head high in the south; the bright star *Alfard*, the Solitary One, marking its heart, whilst the Cup (*Crater*) and Crow (*Corvus*) stand on its back.

Due south, the Sickle in the Lion (*Leo*) now stands with upright handle. Between Leo and the eastern horizon, is the magnificent constellation (*Virgo*), the Virgin, with its resplendent *Spica*. The five-third magnitude stars, above, were called by the Arabs, the "Retreat of the Howling Dog." Due east and high up, above the Virgin and the Lion, we see (*Coma Berenices*), the hair of Queen Berenice, and between this constellation, and the tail of the Great Bear, we see the Hunting Dogs (*Canes* Venatici). The Herdsman (Boötes) is pursuing the Great Bear, and below the shoulder stars of the Herdsman, we see the Crown (*Corona Borealis*), near which, on the right, low down and due east, the head of the Serpent (*Serpeus*) is rising. *Hercules* is rising in the northeast.

The constellations can be observed in these positions, at 9 o'clock on April 7th, at 8:30 o'clock on April 14th, and at 8 o'clock on April 22d.

LEO, THE LION.

Leo, the Lion is one of the most glorious constellations to be seen during the month of April, containing as it does, an unusual number of bright stars. It has



THE CONSTELLATIONS AT 9 P. M., APRIL 1, 1897.

ninety-five visible stars, of which two are of the 1st magnitude, two of the 2d, six of the 3d, and fifteen of the 4th.

"Two splendid stars of highest dignity,
Two of the second class the Lion boasts."

According to Grecian mythology, the Lion represents the formidable animal which was slain by Hercules, and afterwards placed among the stars by Jupiter, in memory of the dread conflict. The Lion is an emblem of violence and fury,

and its representation in the zodiac, signified the intense heat occasioned by the Sun when it enteres that part of the ecliptic. The Egyptians were much annoyed by lions during the heat of the summer, as at that season they left the desert regions, and haunted the banks of the Nile, which had then reached its greatest elevation. This may account for the Lion being placed among the signs of the zodiac, at this season of the year.

Regulus, Alpha Leonis.

Regulus, is the brightest star in this constellation, being of the first magnitude, but inferior in brilliancy to *Arcturus*, in the constellation of Bootes, *Spica*, in the Virgin, or *Capella*, in Auriga. Regulus is a dazzling white, and it is interesting to compare its color with that of Arcturus which is of a ruddy hue, and Capella with its pearly luster. Like most bright white stars, it has a small blue companion star, which "seems as if steeped in indigo." It is between the eighth and ninth magnitude, and is in turn, closely double, according to the observations made by Winlock at Washington. "From the measurements made by Dr. Elkin at Yale, with the heliometer, in 1888, Regulus has a parallax of 0″.093. Its distance in light-years is 35.1; its proper motion 0.27, and its rate in miles per second, 8.5." (*System of the Stars*, p. 405, Agnes M. Clerke).

Great use is made of Regulus for determining longitude at sea, as it is one of the nine conspicuous stars lying along the Moon's path, used by nautical men for this purpose. (These stars are called the Nautical stars, and their names are Arietis, Aldebaran, Pollux, Regulus, Spica Virginis, Antares, Altair, Fomalhaut and Markab). The latitude of Regulus, or distance from the ecliptic, is less than half a degree; but its declination, or distance from the equinoctial is nearly 13° north, so that its meridian altitude will be just equal to that of the Sun on the 19th of August. Its right ascension is very nearly 150°. It therefore culminates about 9 o'clock on the 6th of April.

Denebola.

The next brightest star in Leo is Denebola (Beta Leonis), which is of the first magnitude, and is distinguished on account of its great brilliancy. It has a bluish tinge in its rays, whilst it has a companion star of a dull red color. "South of Denebola, at a distance of nineteen minutes of arc, or somewhere more than half the apparent diameter of the Moon, you will see a little star of the sixth magnitude, which is one of the several "companions" for which Denebola, is celebrated. There is another star of the eighth magnitude in the same direction from Denebola, but at a distance of less than five minutes, and this you may be able to glimpse with a powerful field-glass under favorable conditions. I have seen it well with a field-glass of 1.6-inch aperture, and a magnifying power of seven times. But it requires an experienced eye and steady vision to catch this sky twinkler. (*Astronomy with an Opera Glass*, p. 13, Garrett P. Serviss).

Denebola is 35½° W. of Arcturus, and about the same distance N.W. of Spica Virginis, and forms with them a large equilateral triangle on the S.E. It also forms with Arcturus and Cor Caroli, a similar figure, nearly as large on the N.E. and these two triangles being joined, are called the Diamond of Virgo.

Leading Brilliants in the Sickle.

Next to Regulus, *Eta* Leonis, is the second star in the handle of the Sickle. It is 5° N. of Regulus, and is between the 3d and 4th magnitudes.

Gamma Leonis, is the first star in the blade of the sickle, and is 4° in a northeast direction from *Eta* Leonis. It is of the 2d magnitude, and is one of the fin-

est binaries in the northern sky, its period being about 400 years. It is a golden-yellow star, and it is interesting to compare its color with that of Regulus. Its companion star is of the 4th magnitude, and at a distance of 3 1/5 seconds. This double star was observed by Sir William Herschel in 1784, and he described both the stars as being white, the smaller one inclining slightly to red. In 1837, they appeared golden and yellow, and reddish-green to Struve, whilst Admiral Smyth describes them as "bright-orange and greenish and greenish-yellow," and such they still remain. Undoubtedly a change has taken place in their color, since they were first observed by Herschel. (An illustration showing how this double star should appear, when seen with a power of 160, (three-inch telescope), is to be found on p. 96, of *Hours with a Three-inch Telescope*, by Capt. Wm. Noble, published by Longmans & Co., New York). In the neighborhood of *Gamma* Leonis, he tells us, that "the student will find himself in a rich region of nebulæ."

Zeta Leonis, is the second star in the blade of the Sickle, and is of the third magnitude and 4° north of Gamma.

Mu Leonis, is the third star in the blade of the Sickle, and 6° west of Zeta. It is of the third magnitude.

Epsilon Leonis, is 2½° S. W. of Mu, and is a little within the curve of the Sickle. Near Epsilon are two seventh-magnitude stars, making a beautiful little triangle, as you will see in the illustration given on p. 12 in *Astronomy with an Opera Glass*.

Iota Leonis.

Iota Leonis, is a difficult object to observe even with a three-inch telescope, Captain Noble tells us, it is one which will severely tax the powers, both optical and visual, of the observer. The components are only 2″.4 apart, and the smaller scarcely exceeds the eighth magnitude. It is of a light blue color, whilst the brighter and larger star is of the fourth magnitude and pale yellow.

R Leonis.

R Leonis is a group of four stars, of which one is crimson. It is variable, its period being 312 days, and it ranges between the 5th and 10th magnitudes. It is to be found half way between Regulus and Epsilon. R. A., $9^h\ 41^m\ 39^s$; Decl. + 11° 56′.5. Hind describes it as follows: "It is one of the most fiery looking variables on our list—fiery in every stage from maximum to minimum, and is really a fine telescopic object in a dark sky, about the time of greatest brilliancy, when its color forms a charming contrast with the steady white light of the 6th magnitude star, a little to the N." A line from (α) Regulus to Procyon will pass within ½° S. of this star, 5¼° from Regulus (α). (The Amateur Telescopist's Handbook, p. 134, by Frank M. Gibson, published by Longmans & Co., New York).

Nebulæ in Leo.

In the above book, just referred to, an account is given of some of the nebulæ to be found in the constellation of Leo. For instance, a lucid, round white nebula, is 8¾° due E. of Regulus. R. A. $10^h\ 38^m\ 10^s$, Decl. + 12° 16′.3. About ¾° E. and somewhat N. of this, follows another round but paler nebula. (96 M., H. 2194).

A little east from the last object, and ⅔° north, is a round nebula brightening towards the centre. R. A. $10^h\ 42^m\ 1^s$, Decl. + 13° 9′.4. (H. 2203).

A faint round nebula, forms a pair with the last object. R. A. $10^h\ 42^m\ 28^s$, Decl. + 13° 12′.3. (H. 2207).

A line from Gamma Virginis carried ¾° under Eta Virgo, and 18° on, will

reach a pale white, well defined elongated nebula. R. A. $11^h\ 0^m\ 10^s$, Decl. $+\ 0°$ 33′.5. (H. 2301).

Less than 1° S. of a line from Denebola to Regulus, 7½° from Denebola, are two nebulæ, one being 65 Messier, Herschel 2373, the other 66 Messier, Herschel 2377.

Radiant Point of Leonids.

Great interest is attached to the constellation Leo, because it is from this part of the heavens, and near Gamma, that the famous November meteor showers of 1833 and 1866, appeared to *radiate*. That is their paths produced backward all intersect a common point (or nearly so), which is called "the *radiant*." As an old lady expressed it, in speaking of the meteoric shower of 1833, "The sky looked like a great umbrella." The meteors which appear near the *radiant* are stationary, or have paths extremely short, while those which appear at a distance from it have long courses. The radiant keeps its place among the stars unchanged, during the whole continuance of the shower, and the shower is named accordingly. Thus we have the meteor-shower of the *Leonids* whose radiant is in the constellation Leo. (General Astronomy, p. 441, Professor C. A. Young).

Leo Minor.

The Lesser Lion (Leo Minor) is a constellation of little importance. It was formed by Hevelius, out of the stars which were to be found between the zodiacal constellation of Leo on the south, and Ursa Major on the north. Its mean right ascension is $10^h\ 20^m$, Decl. $+\ 38°$. There are 96 stars in this constellation, one of the third magnitude and three of the fourth magnitude.

This insignificant little constellation has not even any legend to make it interesting, and in fact, as Professor Young says, "It contains nothing deserving special notice. The same remark holds good as to *Sextans*, the Sextant, and even more emphatically."

Hydra, the Serpent.

Hydra, on the contrary is a large and important constellation, covering a space of more than 100 degrees, and stretching through more than six hours of right ascension. Mean R. A. $11^h\ 26^m$, Decl. $-\ 17°$; stars, 370 with one of the second magnitude, three of the third, and twelve of the fourth. In his *Elements of Descriptive Astronomy*, Professor Herbert A. Howe, (on page 284), gives the following directions for locating Hydra. "A line from Polaris through the middle of the triangle which forms the head of the Great Bear, carried on through Cancer, meets the head of Hydra, which is just beyond Cancer." Thence it may be traced in a south and east direction, by following the dotted line of the map. A line from Polaris through Kappa, passing in front of the Sickle in Leo, meets α, which is called Cor Hydræ.

Description of Cor Hydræ.

The bright star Cor Hydræ, or "The Serpent's Heart," is also known as Alphard, or the Solitary One. Its Right Ascension is $9^h\ 22^m\ 11^s$; and its declination $-\ 8°\ 10'.9$. Cor Hydræ is of a rich orange hue, and is of the second magnitude, whilst it is accompanied by a companion star, of pale green hue, of the tenth magnitude. It is situated in the heart of the Hydra, and as there is no other bright star near it, it glows in lonely grandeur, "monarch of all it surveys." An imaginary line drawn from Gamma Leonis through Regulus, will point out Cor Hydræ, at the distance of 23°. It comes to the meridian at about 20 minutes before 9 o'clock on the 1st of April.

Head of Hydra.

The head of the Serpent, is marked by four stars of the fourth magnitude, 2½° and 4° apart. The three upper stars in the head, form a small arch, and may be known by two very small stars just below the middle one, making with it a very small triangle. The three western stars in the head also make a beautiful triangle. When the head of Hydra is on the meridian, its other extremity is many degrees below the horizon, so that its whole length cannot be traced out in the heavens until its centre, or the Cup (*Crater*) is on the meridian.

Epsilon Hydrae is the northernmost star in the head, and is accompanied by a blue companion of the eighth magnitude, at a distance of 3″.5. It is difficult to observe it with a three-inch telescope, Noble tells us, "on account of the proximity of its components, and of their disparity in size."

Other Objects of Interest in Hydra.

β Hydrae is of the third magnitude, R. A. (1855) $0^h\ 18^m\ 4^s$ Decl. — 78° 4.3. Its motion is 2″.2. (System of the Stars, p. 406. Table IV. Communications by Professor E. Schönfeld, of Bonn).

U Hydrae, R. A. $10^h\ 32^m\ 6^s$, Decl. — 12° 52′. The range of variation is from 4.5 to 6.3. Its period in days, being 194.65. (Lessons in Astronomy, p. 342, Table IV. The principal variable stars. By C. A. Young).

R Hydrae, R. A. $13^h\ 24^m\ 2^s$, Decl. — 22° 46′. Range of variation 3.5 to 9.7. Period in days, 496 91 and its period is shortening. In 1708 it extended to 500 days, it is now comprised in 434. (Chandler, *ib.* No. 2463). "The advent of maximum brightness is attended by a blaze of hydrogen." (*System of the Stars*, p. 114).

"Its extreme magnitudes during visibility are 4 and 10. It is of a pale orange-yellow tint, and has a distant greenish eighth magnitude companion." (*The Amateur Telescopist's Handbook*, p. 132. Frank M. Gibson).

V Hydrae is No. 16 of Lalande's Catalogue, and No. 136 of Schjellerup's Red Stars, and was recorded by Dr. Copeland at Dunsink, March 22d, 1876, as "brown red," and of 7.2 magnitude. But three years later, Dr. Dreyer found it risen to the sixth magnitude, and of a "most magnificent copper red," while Birmingham observed it in 1874 as of the eighth, Dunér in 1884, down to 9.5 magnitude. Its fluctuations of light are thus very considerable. (*System of the Stars*, p. 152. By Agnes M. Clerke).

Planetary Nebula.

About 2° south of Mu Hydrae, is a very wonderful object. "It is No. 27 of Herschel's fourth catalogue, and is one of the most remarkable planetary nebulæ in the heavens. Unlike nebulæ generally, this will bear considerable magnifying power. It will be seen as a pale blue disc, looking just like the ghost of Jupiter. As Huggins has shown that it is gaseous, the sharpness of its outline is very curious." (*Hours with a Three-inch Telescope*, p. 97. Capt. Wm. Noble).

Legend of Hydra.

According to Grecian mythology, the Hydra was a terrible monster, which infested the neighborhood of the Lake Lerna, in the Peloponnesus. It had a hundred heads according to Diodorus; fifty, according to Simonides; and nine, according to other authorities. As soon as one of these heads was cut off, two immediately grew up again.

> "He raised a hundred hissing heads in air,
> When one I lopped, up sprang a dreadful pair."

To destroy this fearful monster, Hercules applied a burning iron to the wound, as soon as he cut off a head. While Hercules was destroying the Hydra, Juno, jealous of his glory, sent a sea-crab to bite his foot. This new enemy was soon despatched, and Juno was unable to succeed in her attempts to lesson the fame of Hercules. The conqueror dipped his arrows in the gall of the Hydra, which ever after rendered the wounds inflicted with them incurable and mortal. This fable of the many-headed hydra may be understood to mean nothing more, than that the marshes of Lerna were infested with a multitude of serpents, which seemed to multiply as fast as they were destroyed. (Burritt's *Geography of the Heavens*, pp. 84, 85).

Corvus and Crater.

Corvus and Crater are two constellations resting on the back of Hydra. The constellation Crater represents in the olden maps, a cup tilted on one side, and "it has been regarded as the original goblet out of which Noah first took his wine, though since put to this higher use." (*Easy Star Lessons*, p. 90, by R. A. Proctor). As for Corvus, the crow, "one of the legends avers that it is the daughter of the king of Phocis, who was transformed into a crow to escape the pursuit of Neptune. She is certainly safe in her present guise." (*Astronomy with an Opera Glass*, p. 26.) According to another legend the Crow was once of the purest white, but was changed to its present color, for making mischief. A fit punishment for such a fault!

"The raven once in snowy plumes was drest,
White as the whitest dove's unsullied breast,
Fair as the guardian of the capitol,
Soft as the Swan; a large and lovely fowl:
His tongue, his prating tongue, had changed him quite,
To sooty blackness from the purest white."

Description of the Crater.

Crater may be distinguished by means of six stars of the 4th magnitude, forming a beautiful crescent, opening to the west. The centre of this group is about 15° below the equinoctial, and directly south of the hinder feet of Leo. The Crescent form of the stars in the cup is so striking and well defined, when the Moon is absent, that no other description is necessary to point them out. Its center comes to the meridian about two hours after Cor Hydræ, on the same evening; and consequently it culminates at 9 o'clock, one month after Alphard does.

The mean R. A. of Crater is $11^h\ 15^m$, Decl. $-18°$; stars 95.

Alkes (Alpha Crateris) is situated in the bottom of the Cup, and may be seen 24° S E. of it, and belongs both to Crater and Hydra. "It is a fine star, notable for its two beautiful companions in the field. *A* is of the fourth magnitude and o an orange tint; *B* of the eighth magnitude and of an intense blood color; *C* is of the ninth magnitude, and pale blue." (The Amateur Telescopist's Handbook, p. 120, Frank M. Gibson) "*Alkes* is far from being the brightest star in the constellation, and may be assumed to have diminished considerably in brilliancy since it was entitled α by Bayer. It will be easily found, however, by means of the observer's star maps. If now the telescope be directed to Alkes, there will be found following him at a distance of 42'.5, and about one minute southerly, a small red star, R Crateris. Like most red stars this one is a variable, and its light is growing dim. It varies from the 8th to the 9th magnitude. A somewhat smaller blue star may be seen in the same field." (Half Hours with the Telescope p. 54, by R. A. Proctor).

17 Crateris is an easy double star, with prettily contrasted colors, when observed with a three-inch telescope.

DESCRIPTION OF CORVUS.

Corvus is a small, and unimportant constellation, situated on the eastern part of Hydra, 15° east of the Cup, and is on the same meridian with Coma Berenices, but as far south of the equinoctial as Coma Berenices is north of it. It therefore culminates at the same time, on the 12th of May. Mean R. A. $12^h\ 15^m$, Decl. — 18°; stars 61.

This constellation of Corvus is readily distinguished by means of three stars of the third magnitude, and one of the fourth forming a trapezium or irregular square, the two upper ones being about 3½° apart, and the two lower ones 6° apart. The brightest of the two upper stars on the left is Delta, and sometimes called *Algorab*, is situated in the east wing of the Crow. It has nearly the same declination south as Sirius has and is on the meridian about the 13th of May. It is a fine double star, one component being of the third magnitude, and pale yellow; the other component being of the eighth magnitude, and purple.

Beta, on the back of Hydra, and nearly 7° south of Delta (Algorab) is in the foot of the Crow. It is of the third magnitude, and of an orange hue. It is accompanied by two distant companions. One is of the seventh magnitude, and of a greenish hue; the other of the eighth magnitude and dull grey.

About three-quarters of the way, upon an imaginary line drawn from Alpha to Delta Corvi, will be found a nebula, numbered 65, in Sir W. Herschel's first catalogue.

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury begins the month behind the Sun, being at superior conjunction April 1. He will become visible as evening star during the last week of the month, reaching greatest elongation east from the Sun, 20° 43′, April 28. One should then look almost due west an hour after sunset in order to see the planet.

Venus will by that time have vanished from sight, since she will be at inferior conjunction, *i. e.*, between the Earth and Sun on April 27 at 8^h A. M., Central Standard Time. Venus will then be 5° 43′ north of the apparent center of the Sun. These days when Venus is close to the Sun with her dark side turned toward us will afford splendid opportunities for testing that much disputed question whether or not the outline of the unilluminated hemisphere of the planet is visible. Certain observers have repeatedly stated that this was true, some saying that the dark hemisphere was brighter, others darker, than the surrounding sky.

During the past month it has not been at all difficult to see Venus in full sunlight in the middle of the afternoon. We have several times picked up the planet without any guidance other than a knowledge of the approximate distance and direction from the Sun. On April 17 Venus and Mercury will be in conjunction, Mercury being 5° south of Venus.

Mars is near the feet of Gemini, the Twins, and is moving eastward. On April 8 Mars will pass very close to the star ε Geminorum, and on the next morning will be in conjunction with the Moon, 50′ south of the latter, as seen from the center of the Earth.

Jupiter, in Leo, a little way east from Regulus, is in good position for observation, being near the meridian at a high altitude at nine o'clock in the evening. The Moon will pass Jupiter on the morning of April 13. Jupiter's apparent motion will be very slow in April. He will be stationary in right ascension on April 26 and after that will move eastward.

Saturn is near the meridian at 3^h A. M. but at a rather low altitude. The Moon will pass Saturn on the morning of April 19.

Uranus is in the constellation Scorpio near Saturn and may be observed in the morning hours.

Neptune in Taurus has passed his best position for the year.

Occultations Visible at Washington.

Date 1897.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
April 5	*g* Pleiadum	6.3	7	51	143	8	27	210	0	35
5	19 Tauri	5.0	7	51	94	8	53	259	1	3
5	21 Tauri	7.0	8	13	76	9	13	278	1	0
5	20 Tauri	5.0	8	14	121	9	5	233	0	51
5	22 Tauri	7.0	8	16	82	9	17	272	1	1
11	π^1 Cancri	6.3	12	26	163	13	9	255	0	43
11	π^2 Cancri	6.0	13	31	93	14	20	320	0	49
16	75 Virginis	6 0	8	46	108	9	50	321	1	4
18	*b* Scorpii	5.3	15	6	45	16	49	331	0	43

Occultation of the Pleiades, April 5, 1897.—A rare opportunity to witness several occultations on the same night and at a convenient hour, will be afforded on April 5 when the Moon passes over the northern portion of the Pleiades group, occulting the five stars *g* Pleiadum and 19, 20, 21 and 22 Tauri, all within the space of an hour and a half in the early evening.

Names of New Asteroids.—The following names have been given to the asteroids discovered by Wolf in 1896:

Number.	Name.	Discovered.
(412)	Elisabetha	Jan. 7, 1896
(413)	Edburga	Jan. 7, "
(420)	Bertholda	Sept. 3, 1896
(421)	Zähringia	Sept. 3, "

—*Astronomische Nachrichten*, No. 3404

Sunspots.—On January 1st the only sunspots visible in a four-inch telescope were the components of a small penumbral group scattered longitudinally over a few degrees in the southeast quadrant of the solar disk. On the days following

the group was decreased to one which crossed the disk alone. On Jan. 3d the view obtained was indistinct on account of clouds, but on the morning of the 4th the air was clear, and a large spot with a dark umbra, and a long penumbral train curving remarkably in the foreshortened view, was several degrees inside the east limb. During the following week it was distinctly visible to the naked

eye. It happens that on the Jan. 4th and 5th the solar axis nearly corresponds with our meridian at noon, so that the position of a spot can be found pretty accurately even with such simple appliances as Thompson's disks; and by this means the most northerly portion was seen to be within a few degrees of the solar equator. This equatorial zone is not often subject to disturbance, as the allotted sunspot zones are from 5° to 40° north and south heliographic latitude. In the foreshortened view on the 6th, the resemblance of the umbra to a floral carolla with protruding stamens and curving stem was striking though of no importance except as a curious departure from the usual circular, or pear-shaped form. On the day following it lost this peculiar outline, but was enlarged, and on the 8th, when near the center of the disk, was found to be about 36,000 miles in length, while the encircling penumbra and train extended more than 100,000 miles in a northwest southeast direction. A whitish streak was discernible across a portion of the umbra as if it were about to divide. Some degrees in advance was a small curving spot that kept its relative position and its form unchanged throughout. Before the 11th of January the penumbral train was diminished, and the large umbra, though still undivided, was changed in form. In the foreshortened view of Jan. 14th it seemed to be divided, on the 15th it was close to the limb, and on the day following was undiscernible in the 4 inch telescope.

As a dark umbra is often accompanied with stability, the return of this spot was looked for towards the end of the month, and as the equatorial zones rotate in about 25 days, it was within the east limb at noon on Jan. 29th and at 2:30 P. M. a white space was discernible between them. Jan. 30th it was seen to be in two parts. The next day was cloudy, but on Feb. 1st it was found to consist of three parts, to be diminished in size, and to be bereft of its penumbral train. During the following days the dark umbra of the largest section lost its curved irregular form and assumed the oval or pear-shape so frequent in sunspot formation. When central it measured 27,000 miles in diameter including its penumbral fringe, while the small sections were each a few thousand miles in diameter. It was then distinctly visible without magnifying power. It crossed the remainder of the disk with little change in form, was near the limb on Feb. 11th and was undiscernible on the following day. ROSE O'HALLORAN.

San Francisco, Feb. 18th, 1897.

VARIABLE STARS.

J. A. PARKHURST.

Maxima and Minima of Long Period Variables.

1897 June.

MAXIMA.	Day	MAXIMA, CON'T.	Day	MINIMA.	Day
1386 T Eridani	17	6682 X Ophiuchi	5	1855 R Aurigæ	24
2625 V Geminorum	26	6794 R Lyræ	10	3418 R Carinæ	28
2676 U Monocerotis	4	6905 R Sagittarii	20	5758 X Herculis	7
2815 U Geminorum	23:	7118 X Aquilæ	6	7106 S Vulpeculæ	17
2976 V Cancri	16	7428 V Cygni	20	7257 R Sagittæ	20
4847 S Virginis	8	7577 X Capricorni	22	7299 U Cygni	15
4896 T Centauri	8	7907 U Aquarii	27:	7560 R Vulpeculæ	12
4948 R Can. Ven.	22	7944 T Pegasi	11	3600 R Cassiopeæ	25
5501 S Serpentis	10	8040 S Gruis	14		
5955 R Draconis	8	8230 S Aquarii	24		

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1897.

	d	h
May	2	16
	7	16
	12	16
	17	15
	22	15
	27	15

ALGOL.

May	15	22
	21	15

S CANCRI.

May	6	10
	25	9

δ LIBRAE.

1897.

	d	h
May	7	15
	14	15
	21	15
	28	14

U CORONAE.

May	6	17
	13	15
	20	12
	30	21

RS SAGITTARII.

May	4	13
	9	9
	11	19
	16	15

RS Sagittarii Con.

1897.

d	h
21	11
23	21
28	17

U OPHIUCHI.

May	3	21
	4	18
	5	14
	9	18
	10	14
	11	11
	14	19
	15	15
	16	11

U OPHIUCHI Con

1897.

d	h
19	20
20	16
21	12
24	21
25	17
26	13
29	21
30	18
31	14

W DELPHINI.

May	9	20
	14	15
	19	10

The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue. For the Algol type stars I have given all the minima which occur in the night hours in American and European longitudes, when the star is above the horizon. In the long period ephemeris all the stars are given whose periods are greater than 40 days. A colon after the date signifies doubt.

COMET NOTES.

The Periodic Comet Tempel$_2$-Swift.—In *Bulletin Astronomique*, January, 1897, Mr. J. Bossert gives a note concerning the course of the periodic comet Tempel$_2$-Swift at its return in the spring of 1897. According to this the comet will be so unfavorably situated as probably not to be found.

Search Ephemeris for the Periodic Comet of d'Arrest.—M. Leveau gives an ephemeris of this comet, in *Bulletin Astronomique*, January-1897, extending from March to August. The comet will be brightest in June, but will not at any time be very favorably situated for observation from northern latitudes. At its best it rises only three hours before the Sun and its calculated brightness is not much greater than when it vanished in 1890. The following is the portion of the ephemeris for March:

	R. A.			Decl.		$1 : r^2\Delta^2$
	h	m	s	°	′	
March 6	19	40	13	− 10	12.5	0.101
8		46	37	10	0.8	
10		53	3	9	48.5	
12	19	59	32	9	35.5	
14	20	6	3	9	21.9	0.117
16		12	37	9	7.6	

	R. A.			Decl.		$1 : r^2\Delta^2$
	h	m	s	°	′	
March 18		19	13	8	52.7	
20		25	51	8	37.2	
22		32	32	8	21.0	0.134
24		39	15	8	4.3	
26		46	0	7	47.0	
28		52	47	7	29.2	
30	20	59	36	7	10.8	0.153
April 1	21	6	27	6	51.9	
3		13	19	6	32.6	
5		20	13	6	12.8	
7		27	8	5	52.7	0.172
9		34	4	5	32.2	
11		41	2	5	11.3	
13		48	0	4	50.1	
15	21	55	0	− 4	28.7	0.192

GENERAL NOTES.

This number closes the fourth volume of POPULAR ASTRONOMY and with it a large number of subscriptions expire. It is to be hoped that orders for renewals will be received promptly. It is deemed best not to continue the publication without orders for so doing.

C. M. Charroppin, S. J.—The many friends in the United States of C. M. Charroppin, S. J., will be interested to know of his present location and work. From a private letter of Feb. 23, 1897, he says: "I am getting some good instruments; but as yet I have done very little work in the line of astronomy. Missionary duties take much of my time and the sky is very poor. In Corozal, I had poor instruments, but a good sky; here I have good instruments and a poor sky. My work, of course, is to be on the southern stars. I came to Punta Gorda in order to have a somewhat higher elevation of the southern stars, but I did not expect 29 days of the month to be cloudy at night. On the 5th of February there was here a very pretty mirage."

A description of this Honduras mirage will be given later.

Note on Mr. Miller's article, "Where did Mars get its Moons?"—The dynamical impossibility that the satellites of Mars are captured comets can easily be shown. An undisturbed comet, describing a parabola around the Sun, will be moving at the rate of about 21 miles per second when it reaches the orbit of Mars. The parabolic velocity with respect to Mars at his surface is 3.1 miles per second. That means that a body projected from his surface with a velocity of 3.1 miles per second would recede to an infinite distance unless acted upon by other forces than the attraction of the planet. The parabolic velocity decreases as the distance from the center of force increases; hence a body at the distance of the satellites of Mars could not be retained by the planet even if it had a velocity somewhat less than 3.1 miles per second. Evidently then, a comet several thousand miles distant from Mars moving with a velocity of 21 miles per second could in *no case* be stopped by the planet. If it were not accelerated at all in approaching the planet but were retarded until it had passed around the Sun its velocity would not be decreased so much as 1 mile per second, and even with this retardation it would still be moving in a very long ellipse with a period of more

than 3000 years. During this time it could be within the orbit of Mars only 145 days.

Thus it appears that under the most favorable circumstances Mars could not capture a comet, even in the sense that Jupiter has captured them, and even if they could be captured they could not revolve around the planet as satellites, as could be shown by a more elaborate discussion. Jupiter has been able to capture comets because of his immense mass and the fact that comets at that distance are moving with a velocity of only 11 miles per second. The parabolic velocity with respect to Jupiter at his surface is about 36 miles per second. F. R. M.

Astronomy at the University of Chicago.—The astronomical work of The University of Chicago naturally consists of two parts: the astrophysical research and observational work at the Yerkes Observatory, and the theoretical and mathematical work at the University. The latter, during the absence of Dr. See in Mexico, is given by Dr. Laves and Mr. Moulton.

The following courses will be offered during the year 1897-8:

SPRING QUARTER, 1897.

1. *Theory of Probability and Method of Least Squares.*—Lectures 4 hrs. per week and numerical work 1 hr.

Prerequisite, Differential and Integral Calculus. (Mr. Moulton).

2. *Problem of Three Bodies.*—The theoretical work of Lagrange, Jacobi, Allegret and Radau.

Prerequisite Differential equations. 4 hours per week. (Dr. Laves).

3. *The Dynamics of a System of n Bodies*, based upon Jacobi's Vorlesungen über Dynamick. (Supplement of his collected works).

Prerequisite, Differential equations and analytical mechanics. 4 hours per week. (Dr. Laves).

4. Seminar, 2 hrs. on Saturday.

SUMMER QUARTER, '97.

1. History of Astronomy. (Mr. Moulton).
2. Theories of Double Star Orbits. (Mr. Moulton).
3. Theory of Elliptical Orbits. (Dr. Laves).
4. The Variation of the Arbitrary Constants. (Dr. Laves).
5. Seminar, Use of Astronomical Tables.

AUTUMN QUARTER, '97.

1. General Astronomy. (Mr. Moulton).
2. Theory of Attraction and Figures of Rotating Bodies. (Dr. Laves).
3. Analytical Mechanics, I. (Mr. Moulton).
4. Special Perturbations. (Dr. Laves).
5. Seminar.

WINTER QUARTER, '98.

1. History of the Physical Sciences. (Mr. Moulton).
2. Spherical and Practical Astronomy. (Dr. Laves).
3. Analytical Mechanics, II. (Dr. Laves).
4. Theory of Satellite Orbits. (Mr. Moulton).
5. Seminar.

SPRING QUARTER, '98.

1. Spherical and Practical Astronomy. (Dr. Laves).
2. Theory of Parabolic Orbits. (Mr. Moulton).
3. Secular Variations. (Mr. Moulton).
4. Theory of a Rotatory Body—Nutation and Precession. (Dr. Laves).
5. Seminar.

A more detailed description of the courses and the prerequisites will be published each quarter during the year.

Facts and Theories.—It is a fact that the Moon rotates on its axis in the same time as it revolves around the Earth. It is a consequent fact that, except as hereinafter mentioned, we see always the same hemisphere of the Moon and that, with the same exceptions, its other hemisphere must forever remain an undiscovered country. It is a third fact that the Moon has librations, a libration in longitude, a libration in latitude, and a diurnal libration in consequence of which we are able to look, as it were, over the edge of its disk and see, at one time and another in each month considerably more than one-half of the lunar surface. Facts there are which account for these librations. The diurnal libration is owing to the changed relative position of the observer, the libration in latitude to the inclination of the Moon's orbit, that in longitude to its variable orbital, combined with its uniform axial, motion. So say the astronomers, and I believe they are right.

But this leaves the phenomenon of the Moon's synchronous rotations and revolutions unexplained. No explanation, based on ascertained facts, has, so far as I know, ever been attempted. There are theories and plausible theories, too, to account for the phenomenon, but they seem to break down when brought into contact with the facts which explain the Moon's libration in longitude. One theory is that the phenomenon is due to the Earth's attraction acting on some point of the lunar surface which happens to protrude beyond the general outline; that the Earth, so to speak, lays hold of the protuberance and thus keeps that particular point turned towards its own center of gravity. Another somewhat similar theory has been advanced; namely, that the Moon's center of gravity and center of figure do not coincide, that the mass of one of its hemispheres is the greater and in consequence, that hemisphere is kept always turned towards the Earth by preponderance of attraction.

Is either of these theories true? I think not. Both are plausible and I believe that either would account for the phenomenon they were invented to explain, but if either was true, how could the Moon have a libration in longitude, or in latitude, either? It seems to me that it would have, could have, neither. The attractive force of the Earth, which, acting upon a protuberant point of the Moon or upon its supposed unsymmetrically situated center of gravity, would keep that point or that center in a certain relation to the Earth when the Moon was in one part of its orbit would keep it in the same relation continually. The attraction between the Earth and the point, or center, would be a constant quantity; it would not vary according to the Moon's swifter or slower orbital motion and certainly there could be no libration in longitude, nor, I believe, any in latitude either.

R. M. M'CREARY.

Greensburg, Pa., March 8, 1897.

Professor J. Franz, astronomer at Königsberg Observatory, has been appointed Director of the Observatory at Breslau and Professor at the University in the place of Professor T. Galle, who was retired.

Dr. F. Folie has retired from the Directorship of the Royal Observatory, Brussels.—(*Science*, Feb. 26, 1897).

Professor Simon Newcomb retires from the Nautical Office at Washington, D. C. The city papers give full, and very favorable articles concerning his distinguished services for the government and science generally.

LONGITUDE $4^h\ 44^m\ 28^s.33$ WEST OF GREENWICH.

Standard Eastern Time to Cambridge Sidereal Time.					Cambridge Sidereal Time to Standard Eastern Time.				
	Hours		Min.	Sec.		Hours.		Min.	Sec.	
0	16	20.952	0.000	0.000	0	43	30.726	10.000	1.000	0
1	16	30.782	0.164	0.003	1	43	20.894	9.836	0.997	1
2	16	40.611	0.329	0.005	2	43	11.097	9.672	0.995	2
3	16	50.441	0.493	0.008	3	43	01.237	9.509	0.992	3
4	17	00.270	0.657	0.011	4	42	51.408	9.345	0.989	4
5	17	10.100	0.821	0.014	5	42	41.588	9.181	0.986	5
6	17	19.929	0.986	0.016	6	42	31.749	9.017	0.984	6
7	17	29.759	1.150	0.019	7	42	21.919	8.853	0.981	7
8	17	39.588	1.314	0.022	8	42	12.090	8.689	0.978	8
9	17	49.418	1.478	0.025	9	42	02.260	8.526	0.975	9
10	17	59.248	1.643	0.027	10	41	52.430	8.362	0.973	10
11	18	09.077	1.807	0.030	11	41	42.601	8.198	0.970	11
12	18	18.907	1.971	0.033	12	41	32.771	8.034	0.967	12
13	18	28.736	2.136	0.036	13	41	22.942	7.870	0.965	13
14	18	38.564	2.300	0.038	14	41	13.112	7.706	0.962	14
15	18	48.395	2.464	0.041	15	41	03.283	7.543	0.959	15
16	18	58.225	2.628	0.044	16	40	53.453	7.379	0.956	16
17	19	08.054	2.793	0.047	17	40	43.624	7.215	0.954	17
18	19	17.884	2.957	0.049	18	40	33.794	7.051	0.951	18
19	19	27.714	3.121	0.052	19	40	23.964	6.887	0.948	19
20	19	37.543	3.285	0.055	20	40	14.135	6.723	0.945	20
21	19	47.373	3.450	0.057	21	40	04.305	6.560	0.943	21
22	19	57.202	3.614	0.060	22	39	54.476	6.396	0.940	22
23	20	07.032	3.778	0.063	23	39	44.646	6.232	0.937	23
24			3.943	0.066	24			6.068	0.934	24
25			4.107	0.068	25			5.904	0.932	25
26			4.271	0.071	26			5.741	0.929	26
27			4.435	0.074	27			5.577	0.926	27
28			4.600	0.077	28			5.413	0.924	28
29			4.764	0.079	29			5.249	0.921	29
30			4.928	0.082	30			5.085	0.918	30
31			5.093	0.085	31			4.921	0.915	31
32			5.257	0.088	32			4.758	0.913	32
33			5.421	0.090	33			4.594	0.910	33
34			5.585	0.093	34			4.430	0.907	34
35			5.750	0.096	35			4.266	0.904	35
36			5.914	0.099	36			4.102	0.902	36
37			6.078	0.101	37			3.938	0.899	37
38			6.242	0.104	38			3.775	0.896	38
39			6.407	0.107	39			3.611	0.894	39
40			6.571	0.110	40			3.447	0.891	40
41			6.735	0.112	41			3.283	0.888	41
42			6.900	0.115	42			3.119	0.885	42
43			7.064	0.118	43			2.955	0.883	43
44			7.228	0.120	44			2.798	0.880	44
45			7.392	0.123	45			2.628	0.877	45
46			7.557	0.126	46			2.464	0.874	46
47			7.721	0.129	47			2.300	0.872	47
48			7.885	0.131	48			2.136	0.869	48
49			8.049	0.134	49			1.973	0.866	49
50			8.214	0.137	50			1.809	0.863	50
51			8.378	0.140	51			1.645	0.861	51
52			8.542	0.142	52			1.481	0.858	52
53			8.707	0.145	53			1.317	0.855	53
54			8.871	0.148	54			1.153	0.853	54
55			9.035	0.151	55			0.990	0.850	55
56			9.199	0.153	56			0.826	0.847	56
57			9.364	0.156	57			0.662	0.844	57
58			9.528	0.159	58			0.498	0.842	58
59			9.692	0.162	59			0.334	0.839	59

To the Greenwich Sidereal Time of Greenwich mean noon as given in the American Ephemeris for the given date (Standard Time) add the given Sidereal time plus the correction for h. m. s. given in this table

To the Greenwich Mean Time of Sidereal 0^h at Greenwich (but diminished by one hour) as given in the American Ephemeris for the given date (Standard Time) add the given Cambridge Sidereal Time plus the correction for h. m. s. given in this table. If the result exceeds 24^h repeat with value for preceding date (or add $3^m\ 55^s.91$).

Astronomical Instruments for Sale by George H. E. Tronvelot, 23 rue des Capucins, Meudon, France. These instruments are as follows:

1. A photographic refracting telescope.
2. A comet-seeker.
3. A series of drawings of celestial objects composed of 35 plates.

For further information address as indicated above.

Professor W. W. Hendrickson has been appointed to succeed Professor Simon Newcomb, as superintendent of the American Ephemeris and Nautical Almanac. Professor Hendrickson is a native of Ohio. His naval record is as midshipman in 1862; ensign, 1863; master, 1865; Lieutenant, 1866, and Lieutenant Commander from 1868 to 1873, when he was appointed professor of mathematics in the navy and assigned to the Naval Academy at Annapolis at the head of the department of mathematics.

A Large Spectroscope has just been completed by J. A. Brashear, Allegheny, Pa., for Dr. Hans Hauswaldt, a wealthy scientist of Magdeburg, Germany, where it will be used in physical research.

The powerful concave grating instrument has a focus 21 feet long, and will require a room about 28 feet square in which to operate it. It is to be used for physical investigations of a very interesting character, and the design and construction were settled upon by Professor Brashear and Dr. H. Kayser of the University of Bonn.

It is also very probable that Dr. Hauswaldt will have other powerful instruments of research made by Professor Brashear, as correspondence is now going on in regard to great physical and astronomical instruments that are to be placed in the new laboratory now being equipped by him in Magdeburg. Dr. Hauswaldt has gained considerable fame in Germany by his experiments, and he is sparing nothing in the equippment of his laboratory, which, when complete, will be one of the finest in Europe.

BOOK NOTICE.

Elements of Plane and Spherical Trigonometry by C. W. Crockett, Professor of Mathematics and Astronomy, Rensselaer Polytechnic Institute, American Book Company, New York, Cincinnati, Chicago.

We have been much interested in this new trigonometry in making a study of the author's ideas in presenting the principles of the science, and in making the application of those principles to give the student some thought of its practical use.

Something of an outline of the author's work may be seen in considering the following points.

1. The title to part one is plane and analytical trigonometry. The analytic idea is manifest in the signs of lines and angles in an elemental way, and in carefully considering plane angles and their measurement. The fine print paragraphs interspersed in the text are helpful.

2. On the 17th page right angled triangles are introduced and their systematic study undertaken. The plan is to present an analytic statement of the functions with suitable figures, then construct the simple formulæ, arrange the

formulæ for ready logarithmic computation giving a model of the methods of work and then expect the student to master the several cases in plane right angled triangles. In this the author is different from most others and we think very wisely so.

3. Chapter III is a generalization of the idea of angles based on the analytic idea somewhat extended and illustrated by the simple applications that will readily occur to any experienced teacher. The work of this chapter is well done. The examples are many and well chosen.

4. The remaining chapters to, and including VII, which concludes the plane trigonometry are very full and unusually complete. They contain almost too much matter except for such colleges or schools as can give more time to this branch, (than it is possible to do in general courses), and that means specialization. For such schools this book seems admirably adapted both in plane and spherical trigonometry. We like it so much that it will probably be adopted soon at Carleton College.

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